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Department of Water Resources

BULLETIN No. 182

UPPER SAN DIEGO RIVER FLOOD CONTROL INVESTIGATION

save water
DWR

February 1976

CLAIRE T. DEDRICK
Secretary for Resources
The Resources Agency

EDMUND G. BROWN JR.
Governor
State of California

RONALD B. ROBIE
Director
Department of Water Resources

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February 1976

CLAIRE T. DEDRICK	EDMUND G. BROWN JR.	RONALD B. ROBIE
Secretary for Resources	*Governor*	*Director*
The Resources Agency	State of California	Department of Water Resources

FOREWORD

The mushroom-like growth of California following World War II, particularly in the region south of the Tehachapi Mountains, has produced benefits but has also given rise to some serious problems. One of the more serious problems has been land development in areas subject to flooding.

The Department of Water Resources has investigated such problem areas in cooperation with local agencies. This report presents a discussion of flood hazards in the Upper San Diego River area in San Diego County and is one of a series dealing with this subject. The study area extends along the San Diego River from El Capitan Dam to Mission Dam and includes that portion of San Vicente Creek which extends from San Vicente Dam to the confluence with the San Diego River.

Hydraulic and hydrologic data gathered in 1964 for the Upper San Diego River and a major tributary, San Vicente Creek, have been updated for this report. Alternative flood control plans based on a reconnaissance-level study of both structural and nonstructural measures are evaluated in this report. The plans include concrete-lined channels, earth channels with stone-protected sides, and grass-lined channels, as well as floodplain management. The study concludes that nonstructural measures in the form of floodplain and watershed management, flood warning systems, and flood proofing would provide the best overall means of reducing flood damage in the Upper San Diego River area.

The study was initiated at the request of the San Diego County Department of Sanitation and Flood Control and was jointly funded by San Diego County and the Department of Water Resources. It was closely coordinated with the County and the U. S. Army Corps of Engineers. As a result, the information presented in this report should be useful in the county flood zoning program, the flood insurance program of the Federal Insurance Administration, and the various Corps of Engineers' studies.

Special appreciation for assistance and cooperation in this study is due the U. S. Geological Survey, Corps of Engineers, and the County Department of Sanitation and Flood Control District.

Ronald B. Robie

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Department of Water Resources

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CONVERSION FACTORS

English to Metric System of Measurement

Quantity	English unit	Multiply by	To get metric equivalent
Length	inches (in)	25.4	millimetres (mm)
		.0254	metres (m)
	feet (ft)	.3048	metres (m)
	miles (mi)	1.6093	kilometres (km)
Area	square inches (in^2)	6.4516×10^{-4}	square metres (m^2)
	square feet (ft^2)	.092903	square metres (m^2)
	acres	4046.9	square metres (m^2)
		.40469	hectares (ha)
		.40469	square hectometres (hm^2)
		.0040469	square kilometres (km^2)
	square miles (mi^2)	2.590	square kilometres (km^2)
Volume	gallons (gal)	3.7854	litres (l)
		.0037854	cubic metres (m^3)
	million gallons (10^6 gal)	3785.4	cubic metres (m^3)
	cubic feet (ft^3)	.028317	cubic metres (m^3)
	cubic yards (yd^3)	.76455	cubic metres (m^3)
	acre-feet (ac-ft)	1233.5	cubic metres (m^3)
		.0012335	cubic hectometres (hm^3)
		1.233×10^{-6}	cubic kilometres (km^3)
Volume/Time (Flow)	cubic feet per second (ft^3/s)	28.317	litres per second (l/s)
		.028317	cubic metres per second (m^3/s)
	gallons per minute (gal/min)	.06309	litres per second (l/s)
		6.309×10^{-5}	cubic metres per second (m^3/s)
	million gallons per day (mgd)	.043813	cubic metres per second (m^3/s)
Mass	pounds (lb)	.45359	kilograms (kg)
	tons (short, 2,000 lb)	.90718	tonne (t)
		907.18	kilograms (kg)
Power	horsepower (hp)	0.7460	kilowatts (kW)
Pressure	pounds per square inch (psi)	6894.8	pascal (Pa)
Temperature	Degrees Fahrenheit (°F)	$\frac{tF - 32}{1.8} = tC$	Degrees Celsius (°C)

CHAPTER 1. INTRODUCTION

San Diego County's population has been growing at such a rapid rate that new developments have spread onto floodplains, thereby creating danger to both life and property. Many people have settled in the floodplains, either ignoring or not realizing the ever-present hazard of floods.

San Diego County has, in recent years, taken positive steps to reduce the flood hazard through ordinances providing for the regulation of development in flood-prone areas.

Notwithstanding these actions by the County, there exist today serious flood hazards in the Upper San Diego River area. Recognizing the importance -- indeed, the urgency -- of this problem and the need for lessening the threat of inundation of existing and potential floodplain developments, the County requested the Department of Water Resources to investigate the flood hazards in the Upper San Diego River.

The investigation focused on flood hazards in the Upper San Diego River Basin and along San Vicente Creek. The County of San Diego can use the information gained in this investigation to plan flood control measures that will safeguard lives and property in the floodplain and still allow compatible uses in and adjacent to it.

Objective and Scope of the Investigation

The objective of the investigation was to provide information needed by the County to establish floodplain regulations and improvements that would be effective in reducing the flood hazard.

The following work was accomplished:

1. Updated the hydraulic and hydrologic data on the Upper San Diego River and San Vicente Creek, published in 1964 Bulletin No. 112, titled "San Diego County Flood Hazard Investigation", and reevaluated reservoir operations of the City of San Diego's El Capitan and San Vicente Reservoirs. The hydraulic data derived in this study will be used by the County in its subsequent watershed modeling for flood forecasting.

2. Delineated potential areas of inundation from 10-year and 100-year-frequency floods and determined the floodway, as defined in Chapter 4.

3. Developed alternative flood control plans on a reconnaissance level. This included structural and nonstructural measures that would provide such multipurpose developments as conservation of local flood waters, recreation, and fish and wildlife enhancement.

Study Area

The Upper San Diego River area in San Diego County lies 22 miles north of the International Boundary between the United States and Mexico and is roughly parallel to the boundary. It comprises the San Diego River floodplain from Mission Dam to El Capitan Dam, a length of 15 miles (Figure 1). The study area includes portions of two of the river's tributaries, Forester and San Vicente Creeks. Forester Creek's confluence with the river is 2 miles upstream from Mission Dam and the confluence of San Vicente Creek is 7 miles upstream from the dam. The San Diego River and San Vicente Creek were broken into several reaches for evaluation of flood control benefits and costs.

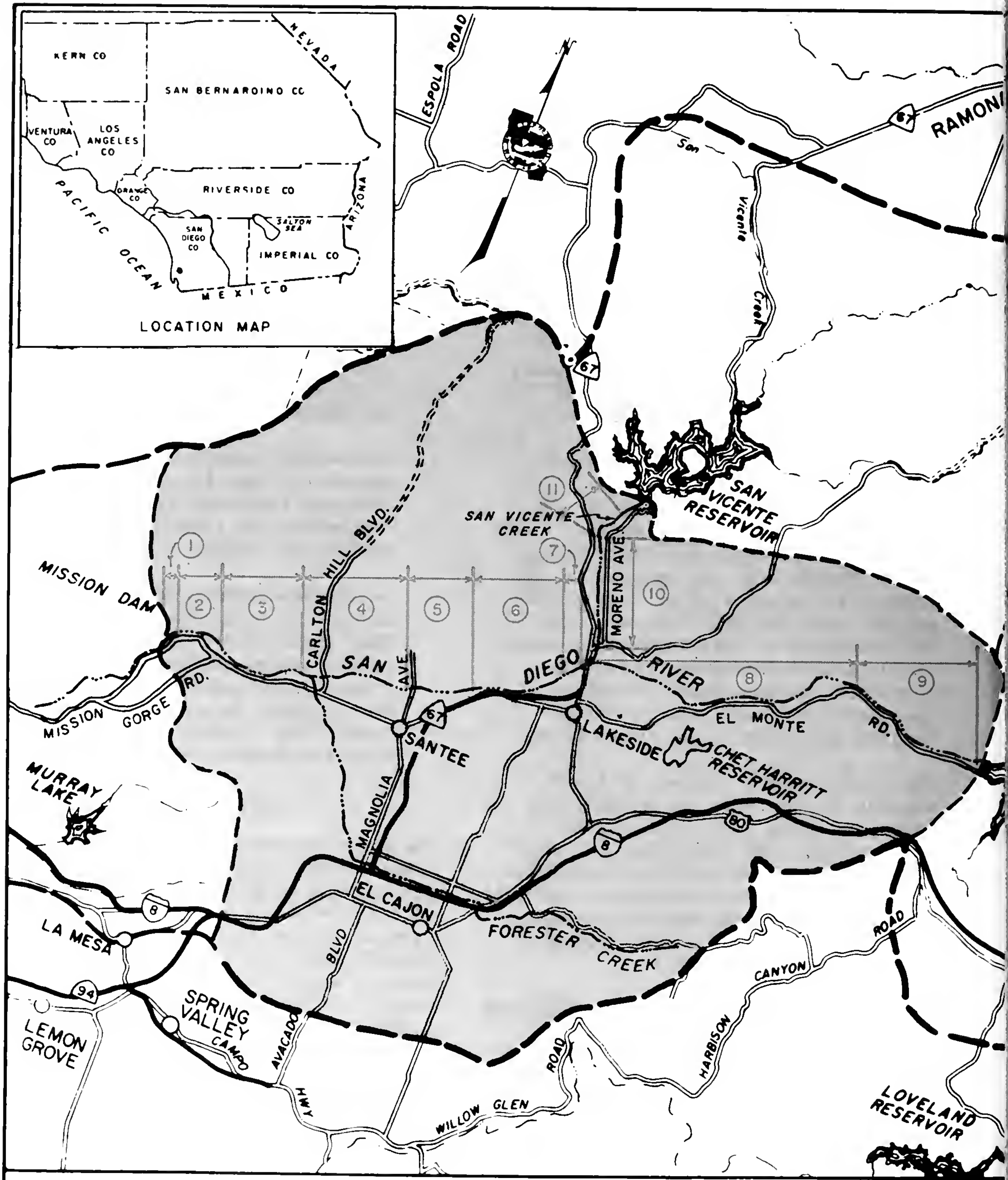
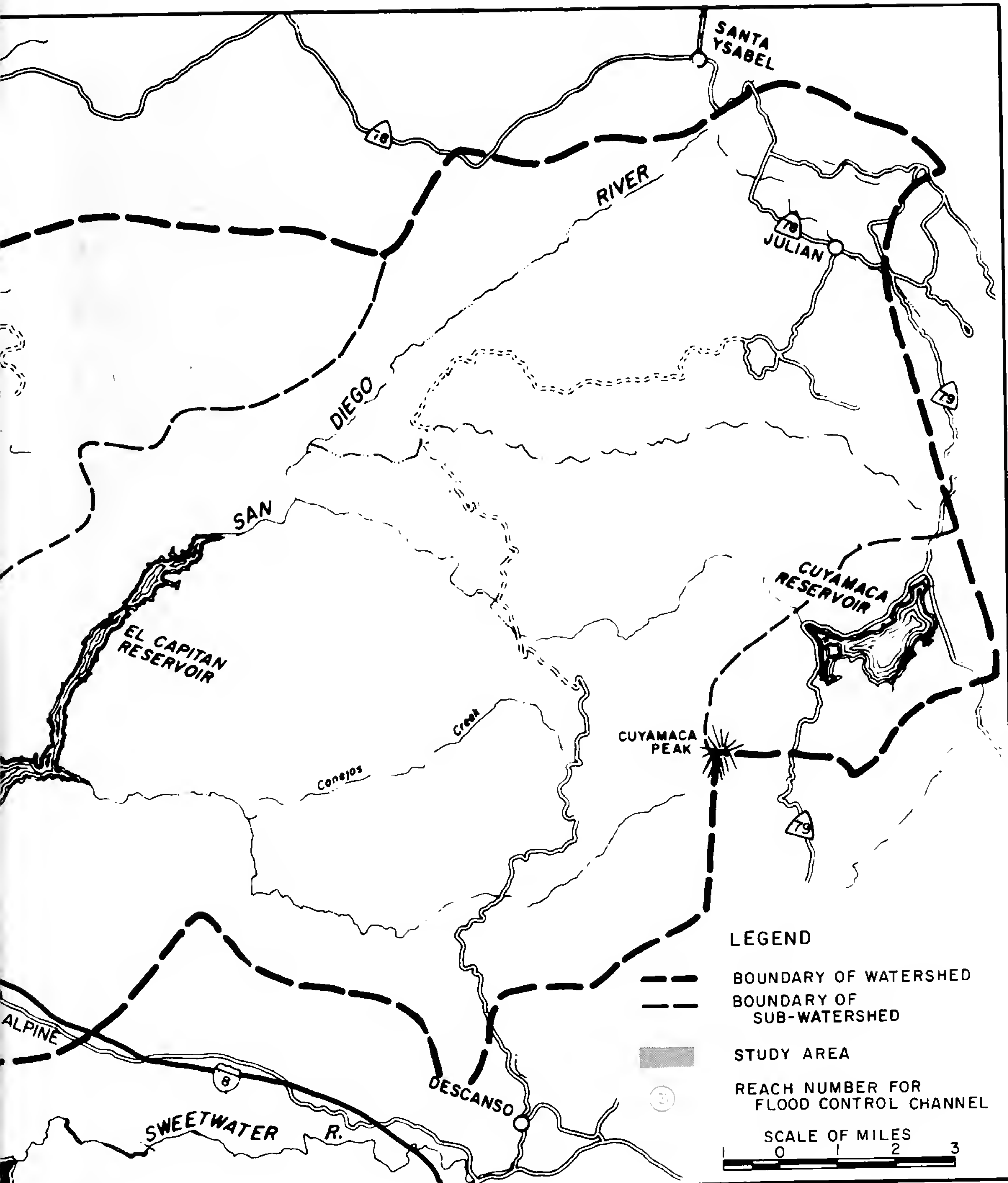


FIGURE I

DEPARTMENT OF WATER RESOURCES, SOUTHERN DISTRICT, 1975



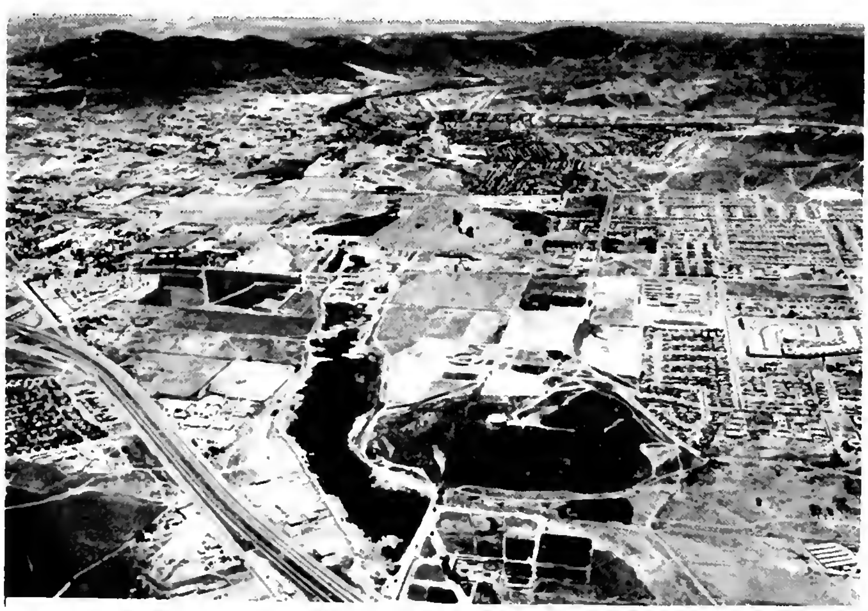
VICINITY MAP

The width of the Upper San Diego River floodplain ranges from 400 feet to less than a mile. At gorges near El Capitan, San Vicente, and Mission Dams, the floodplain narrows to 200 to 300 feet. The elevation of the streambed ranges from 270 feet above mean sea level near Mission Dam to 550 feet at El Capitan Dam.

Along the river, the development in the floodplain consists of farmland, golf courses, commercial sand pits, and a few residences. Along Forester and San Vicente Creeks, the floodplain consists of farmland, residences, and commercial developments.

Santee and Lakeside are the principal communities within the study area. They are located approximately in the center of the study area. According to the 1970 U. S. Census, the population of each community was 26,000, with half or two-thirds of their work force commuting to or near the San Diego metropolitan area. According to the San Diego County Planning Department figures, the population of Santee had increased to 33,000, and the population of Lakeside had increased to 29,000, as of July 1974.

Two downstream views of the San Diego River. Above--from El Capitan Dam. Below--from Lakeside Water Pollution Control Facility.



CHAPTER 2. WATERSHED CONDITIONS

To determine the magnitude of a flood of any given frequency, a number of factors, such as precipitation, past floods, land use, and developments within the watershed influencing runoff characteristics, must be taken into account.

Precipitation

Mean annual precipitation in the watershed tributary to the study area ranges from 12 inches at the lower elevations to 35 inches at the higher elevations. Virtually all the precipitation occurs from November through April. Most of the precipitation results from general winter storms originating in the northern Pacific Ocean. Occasional rainfall is generated by tropical storms.

Floods of Record

The records of major floods along the San Diego River begin in 1825 when high water changed the course of the river. The greatest flood ever reported in the basin occurred in 1862 and the second greatest in 1916. A discharge of 70,200 cubic feet per second (cfs) was estimated at the gaging station on the river near Santee during the 1916 flood, before El Capitan and San Vicente Dams were built. There have been no major floods along the Upper San Diego River since 1941. Some of the major floods that were recorded at the gaging station near Santee are listed in Table 1.

TABLE I

MAJOR FLOODS RECORDED ON SAN DIEGO RIVER NEAR SANTEE

Date	*Discharge in cubic feet per second*
January 27, 1916	70,200*
March 12, 1918	12,000
December 26, 1921	16,700
February 16, 1927	45,400
February 16, 1932	7,400
February 7, 1937	14,200
March 3, 1938	7,350
April 13, 1941	9,250

*Estimated from high watermark

Land Use

Upstream from El Capitan and San Vicente Dams, the watershed consists mostly of undeveloped mountainous terrain that has changed only slightly in the 10 years since Bulletin No. 112 was published.

Downstream from El Capitan and San Vicente Dams, land use changes have occurred to some extent in the overall study area but not in the floodplain. One exception to this exists: in the last ten years a number of single-family dwellings have been built within the floodplain of San Vicente Creek.

The Department conducted land use surveys of the area in 1958 and 1967. The results are presented in Table 2. While the survey data do not coincide with the present period of investigation, they give an indication of the types of land uses in which changes are taking place.

Watershed Developments

El Capitan and San Vicente Reservoirs are both owned and operated by the City of San Diego. Their primary purpose is that of water supply; however, because of the operational characteristics and surcharge storage above the spillway elevation, a measure of flood control is provided by each reservoir.

El Capitan Dam was built in 1935 by hydraulic fill methods. It has a storage capacity of 116,500 acre-feet at the spillway elevation of 750 feet, with a drainage area of 190 square miles.

Because of the recent failure from earthquake of the Van Norman Dam in the San Fernando Valley, a hydraulic fill dam, the Department's Division of Safety of Dams requested all owners of hydraulic fill dams to conduct an investigation of the safety of their dams under seismic loading. Accordingly, the City of San Diego conducted the requested dam safety study for El Capitan Dam. The result of the study showed the maximum water surface elevations should be from 720 feet to 730 feet (spillway elevation 750 feet). The Department established the maximum elevation at 720 feet, which is now considered to be the permanent storage elevation. This reduced level provides emergency storage space and thereby increases flood protection.

San Vicente Dam was built in 1943 and is a concrete gravity dam impounding a reservoir with a storage capacity of 90,000 acre-feet. It is used for storage of local runoff and regulation of water imported through the first San Diego Aqueduct.

TABLE 2
LAND USE IN SAN DIEGO RIVER BASIN
FROM EL CAPITAN AND SAN VICENTE DAMS
TO MISSION DAM

Category and class of land use	1958 Area In acres	1958 Area In percent	1967 Area In acres	1967 Area In percent
Urban and Suburban				
Residential	3,770		6,880	
Commercial	370		770	
Industrial	20		120	
Unsegregated urban and suburban area	600		780	
Subtotals	4,760		8,550	
Included nonwater service area	2,280		3,640	
Gross urban and suburban area	7,040	9.6	12,190	16.7
Irrigated Agriculture				
Alfalfa	90		90	
Pasture	1,090		1,310	
Citrus and subtropical	1,770		1,560	
Truck crops	400		370	
Field crops	10		10	
Deciduous fruits and nuts	70		60	
Small grains	280		220	
Vineyards	40		40	
Subtotals	3,750		3,660	
Fallow	200		160	
Included nonwater service area	400		220	
Gross irrigated agriculture	4,350	6.0	4,040	5.5
Nonirrigated Agriculture	2,650	3.6	2,240	3.1
Active Vegetation	7,810	10.7	7,180	9.8
Unclassified (Mostly chaparral and coastal sage scrub)	51,220	70.1	47,420	64.9
TOTALS	73,070	100.0	73,070	100.00

CHAPTER 3. FLOOD ANALYSIS

To determine potential inundated areas along a river and tributaries for any flood frequency, hydrographs must be derived showing the peak flood and the time of maximum concentration. Where there are reservoirs in the watershed, as is the case here, hydrographs and the storage in the reservoirs serve as important parameters in determining maximum flood peaks.

Flood Hydrograph

The flood hydrograph used in this study was synthesized by taking a series of hydrographs of actual storms for several hydrologically comparable drainage areas. The storm hydrographs were analyzed to determine when peak flows occur, the duration of the hydrograph in hours for various percentages of peak flow, and the length of time of significant flows. The average flood hydrograph was then synthesized from these hydrographs for the following known storms:

1. Temecula Creek at Pauba Canyon
   Feb. 1937; Dec. 24-25, 1940

2. Murrieta Creek at Temecula
   Feb. 1937; Dec. 24-25, 1940;
   Jan. 22-24, 1943

3. Santa Margarita River below the confluence of Murrieta and Temecula Creeks
   Feb. 1937; Dec. 24-25, 1940;
   Jan. 22-24, 1943

4. Santa Margarita River near Fallbrook
   Feb. 1937; Dec. 24-25, 1940;
   Jan. 22-24, 1943

5. Santa Margarita River at Ysidora
   Feb. 1937; Jan. 22-24, 1943

6. San Luis Rey River near Bonsall
   Feb. 27 to Mar. 6, 1938

7. San Luis Rey River at Henshaw Dam
   Jan. 16-21 and Jan. 26-30, 1916

8. Santa Ysabel Creek near Ramona
   Jan. 26-29, 1916

9. Santa Ysabel Creek near Mesa Grande
   Jan. 26-29, 1916

10. San Dieguito River near Bernardo
    Jan. 26-29, 1916

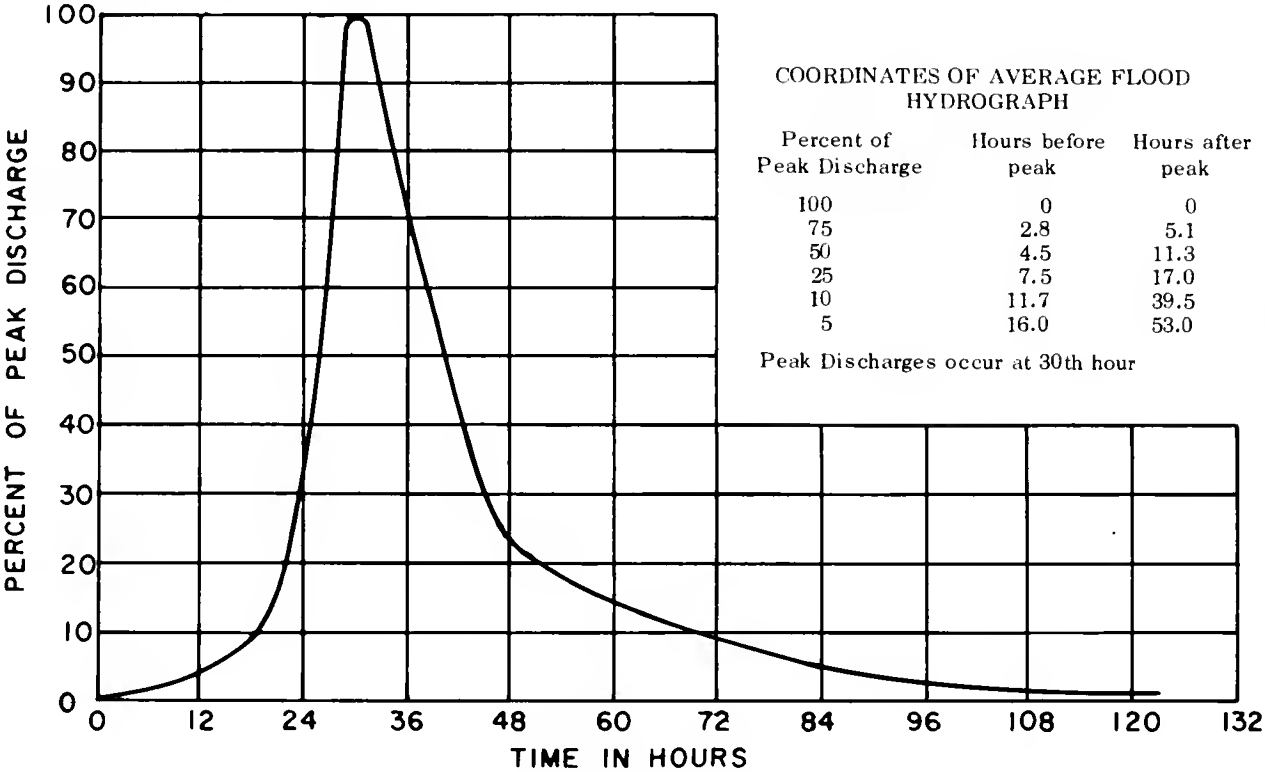
11. Sweetwater River at Sweetwater Dam
    Jan. 27, 1916

Percent of peak discharge by hours and the average synthesized flood hydrograph for coastal San Diego County are shown in Figure 2.

The hydrograph duration selected for the 100-year frequency flood was four days because the 1916 flood, which was one of the greatest on record, extended over a 4-day period and has a recurrence interval of about 100 years. Hydrographs for selected locations along the stream channels were calculated by taking the peak discharges at the desired locations and applying the percent of peak discharge values obtained from Figure 2.

Reservoir Conditions

The storage in El Capitan and San Vicente Reservoirs just prior to a flood inflow has a significant influence on peak discharges downstream of the reservoirs. To establish this storage, frequency curves were developed for water level elevations from historic data. From these curves and the City



COORDINATES OF AVERAGE FLOOD HYDROGRAPH

Percent of Peak Discharge	Hours before peak	Hours after peak
100	0	0
75	2.8	5.1
50	4.5	11.3
25	7.5	17.0
10	11.7	39.5
5	16.0	53.0

Peak Discharges occur at 30th hour

Figure 2 – AVERAGE FLOOD HYDROGRAPH FOR SAN DIEGO COUNTY

of San Diego's anticipated operation of the reservoirs,[1/] the water level elevation was established at three-quarters full for El Capitan Reservoir and full for San Vicente Reservoir at the beginning of the 100-year frequency flood. These assumptions are different from those stated in Bulletin No. 112, where two initial water surface elevation conditions were assumed. Under one condition both reservoirs were assumed to be full and under the other El Capitan was assumed to be half full while San Vicente was two-thirds full.

As mentioned before, the Department directed that the water surface level for El Capitan Reservoir be kept below elevation 720 (30 feet below spillway level) as a precautionary measure against seismic loading. This elevation is for long duration storage and may be exceeded on a temporary basis, such as the initial water level used in this study, which is approximately 10 feet higher. This difference of 10 feet can be attributed to antecedent runoff into the reservoir.

Peak Flood Discharges

The peak discharges were determined from regression equations that were derived in Appendix B, Bulletin No. 112, "San Diego County Flood Hazard Investigation". These equations were revised slightly for this study to reflect the additional years of runoff record available since the publication of that bulletin. These equations were revised by redrawing all the frequency-discharge curves for all the gaging stations utilized in the previous study.

1/As stated in the letter of October 24, 1973, from Mr. R. E. Graham, Assistant City Manager to Mr. Garth A. Fuquay, Chief, Engineering Division, U. S. Army Corps of Engineers, Los Angeles District.

From these curves and considering the same two significant parameters of basin shape and size, regression equations were derived for the 10- and 100-year recurrence interval floods.

The equations indicate peak discharges slightly lower than from the previous equations for the same drainage area. This resulted because the past 10 years of additional record were relatively dry years. The regression equations derived are:

$$Q_{(100\text{-year})} = 1090 \times A^{0.614} \times Sh^{-0.56}$$

$$Q_{(10\text{-year})} = 387 \times A^{0.55} \times Sh^{-0.19}$$

where Q = Discharge in cubic feet per second.

A = Area of drainage basin in square miles

Sh = Shape factor = d/L, where d = diameter of a circle whose area is equal to the area of the drainage basin and

L = Maximum length of basin

Based on the peak flood discharges at various locations and the shape of the hydrographs, the floods were routed through El Capitan and San Vicente

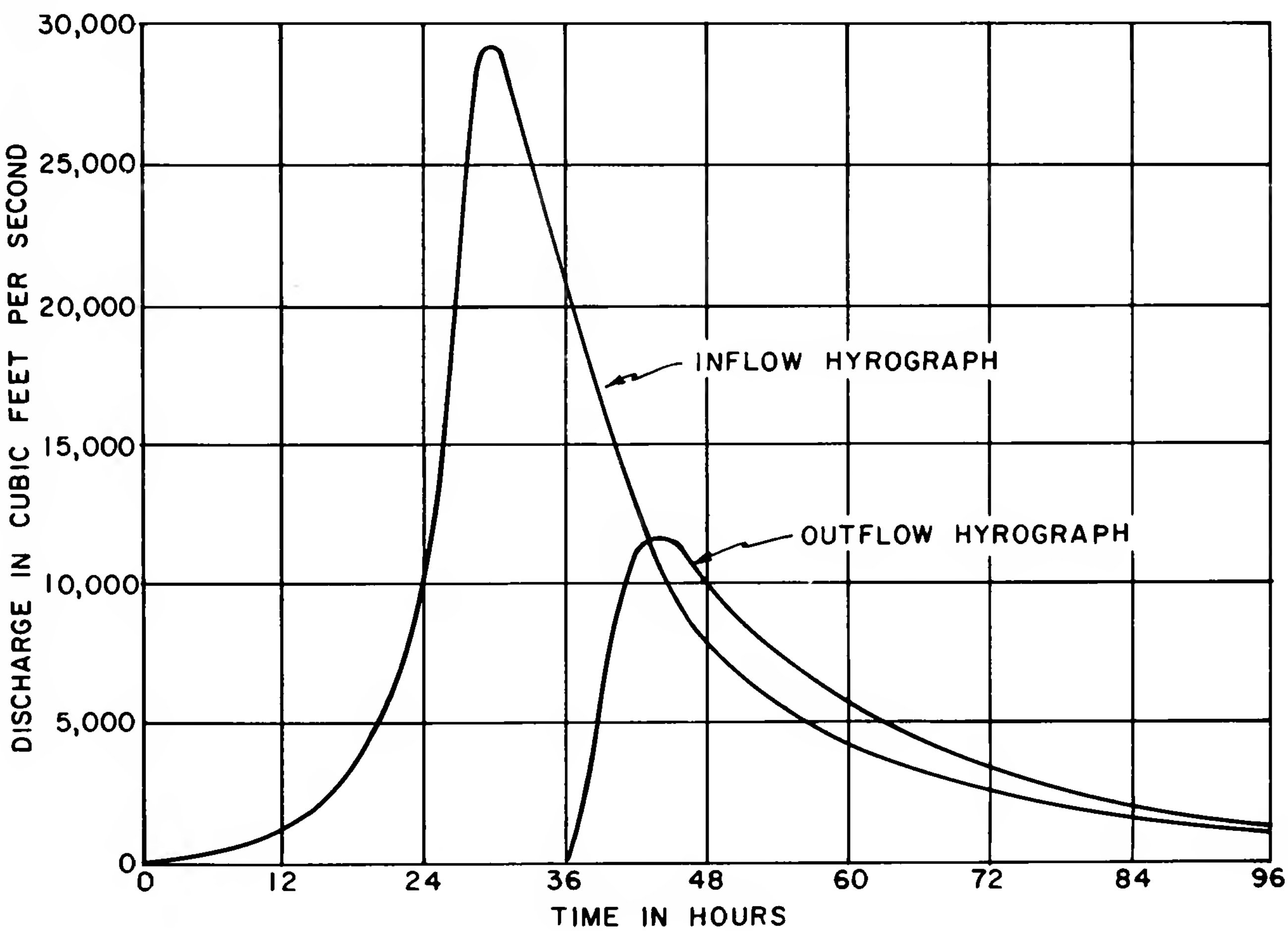


Figure 3 - INFLOW AND OUTFLOW HYDROGRAPHS FOR 100-YEAR FLOOD AT EL CAPITAN RESERVOIR WITH RESERVOIR THREE-QUARTERS FULL INITIALLY

Reservoirs by means of the modified Puls Method. The inflow-outflow hydrograph through El Capitan Dam when the dam is three-fourths full at the beginning of the flood is shown in Figure 3. Outflows from the reservoirs were combined with the natural discharges below the reservoirs to determine estimated maximum discharges at different locations along the San Diego River.

The peak flood discharges estimated for this study vary slightly from the discharges computed by the Department from the derived regression equations. Because discharge data developed by the County and in preliminary studies by the U. S. Army Corps of Engineers differ slightly from those of the Department, the San Diego County Department of Sanitation and Flood Control District recommended for the purpose of consistency that the selected peak flood discharges shown in Table 3 be utilized in this study.

Areas of Potential Inundation and Determination of Floodway

Water surface elevations were determined utilizing the discharges at various points along the San Diego River and its tributaries and the U. S. Army Corps of Engineers HEC-2 computer program. This program utilizes the method which applies Bernoulli's Theorem for the total energy at each cross section and Manning's Formula for the friction head loss between cross sections. Each

TABLE 3
ESTIMATED PEAK FLOOD DISCHARGES FOR SELECTED LOCATIONS ON THE SAN DIEGO RIVER, SAN VICENTE CREEK, AND FORESTER CREEK
In cubic feet per second

Location	*10-year flood*	*100-year flood*
San Diego River		
2 miles downstream from El Monte Park	1,300	19,000
At Wildcat Canyon	2,100	20,000
At confluence with San Vicente Creek	2,500	31,000
At Winter Gardens Boulevard	3,200	32,000
At Cottonwood Avenue	3,500	33,000
0.2 mile upstream of Cuyamaca Street	3,800	34,000
At confluence with Forester Creek	4,500	36,000
0.7 mile downstream from Sycamore Canyon	5,000	37,000
Mission Dam	5,500	38,000
San Vicente Creek		
At Slaughterhouse Canyon	200	13,000
At confluence with San Diego River	1,400	16,000
Forester Creek		
At confluence with San Diego River	3,800	9,200

cross section was divided according to its main channel and overflow areas, and an appropriate roughness coefficient was assigned to each division. The roughness coefficients (Manning's "n" value) were determined by field investigations and verified by comparison with photographic slides from U. S. Geological Survey records and USGS Water Supply Paper 1849, titled "Roughness Characterisitcs of Natural Channels". Expansion and contraction losses were also taken into account to determine head loss between the cross sections.

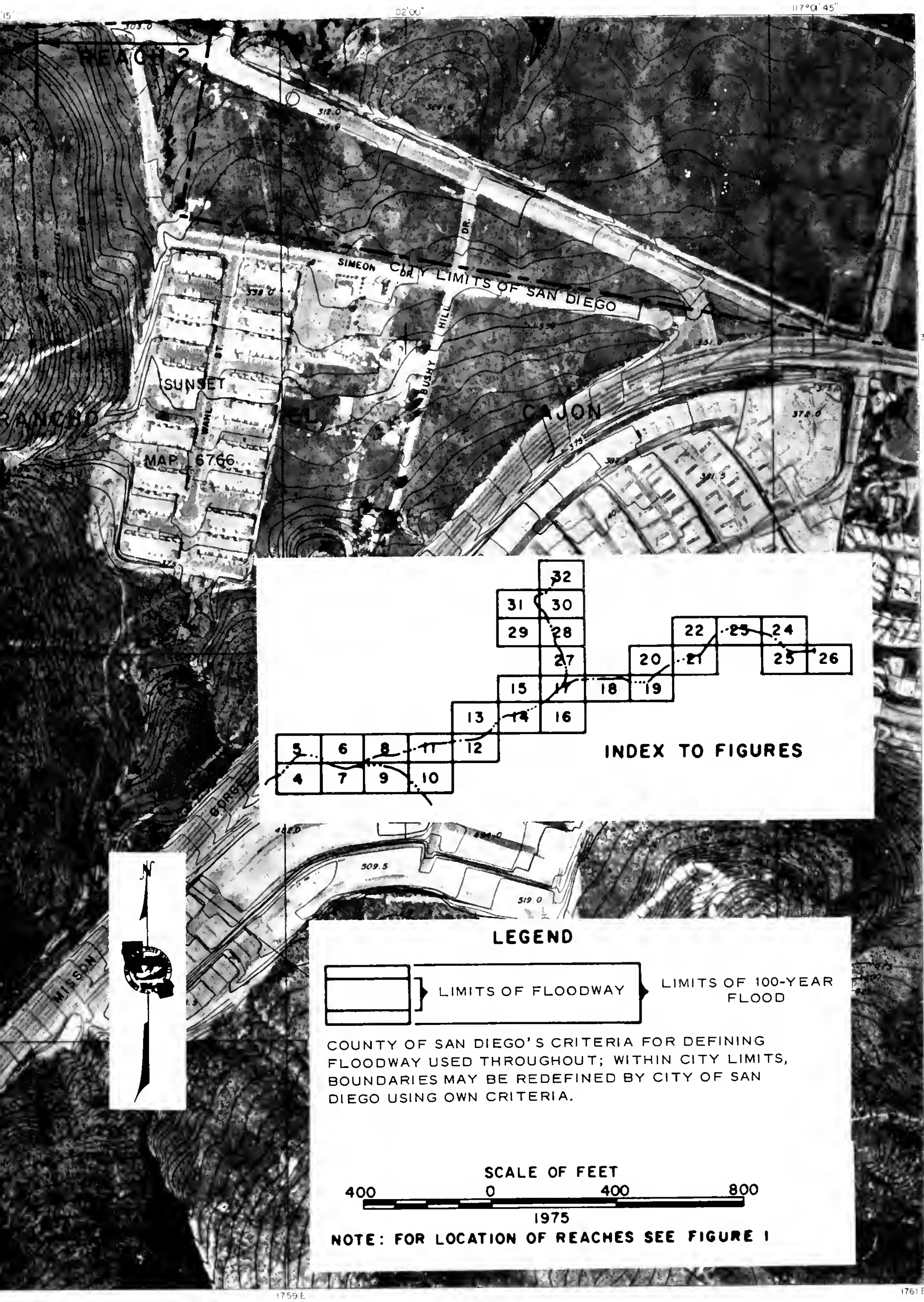
Section lines were drawn on aerial photos, scale 1 inch equals 500 feet, and the cross sections were digitized for use in the computer. The computed water surface elevations for the 10-year and the 100-year floods were then delineated. The floodway lines which were also determined and delineated depict the limits of encroachment of the floodplain. A floodway is defined as that area required to pass the 10-year flood without structural improvements and that area required to pass the 100-year flood without increasing the water surface elevation of that flood more than 1 foot at any point (Chapter 4 and Figure 36).

Figures 4 through 32 show the 100-year-frequency flood lines and floodway, which are predicated on the assumption that bridges will be built in the future at Carlton Hills Boulevard, Cuyamaca Street, and Magnolia Avenue. The criterion was set by the County to be compatible with the requirements of the National Flood Insurance Program where consideration should be given to pending construction. The Cuyamaca Street Bridge has been completed and is scheduled to be opened to traffic in the near future.

San Diego River looking north from Lakeshore Drive--1916 flood

-Union Title Historical Photo Collection

FIGURE 4 - AREAS OF POTENTIAL INUNDATION FROM A 100-YEAR



LOOD AND LOCATION OF FLOODWAY- REACHES I AND 2

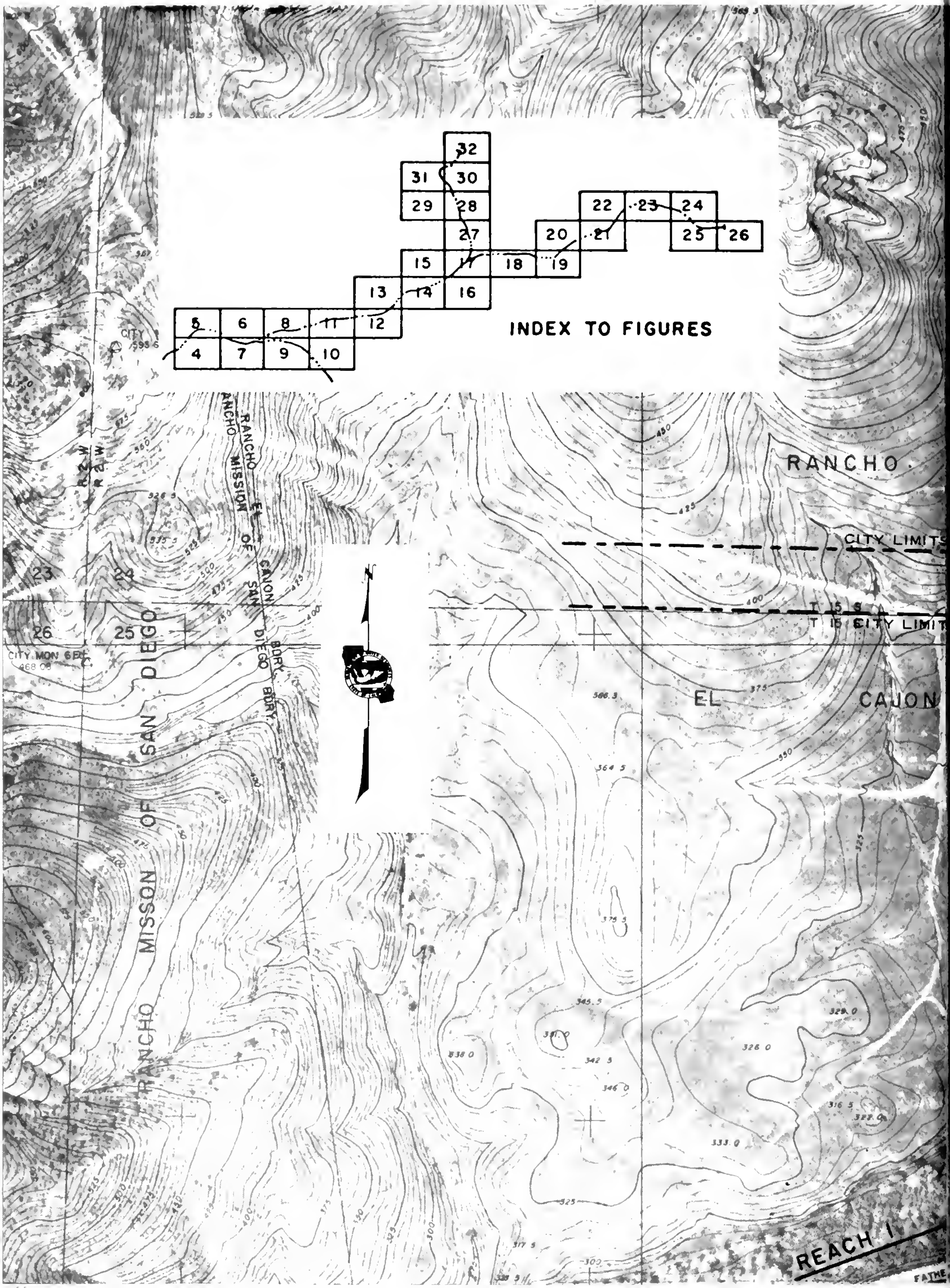
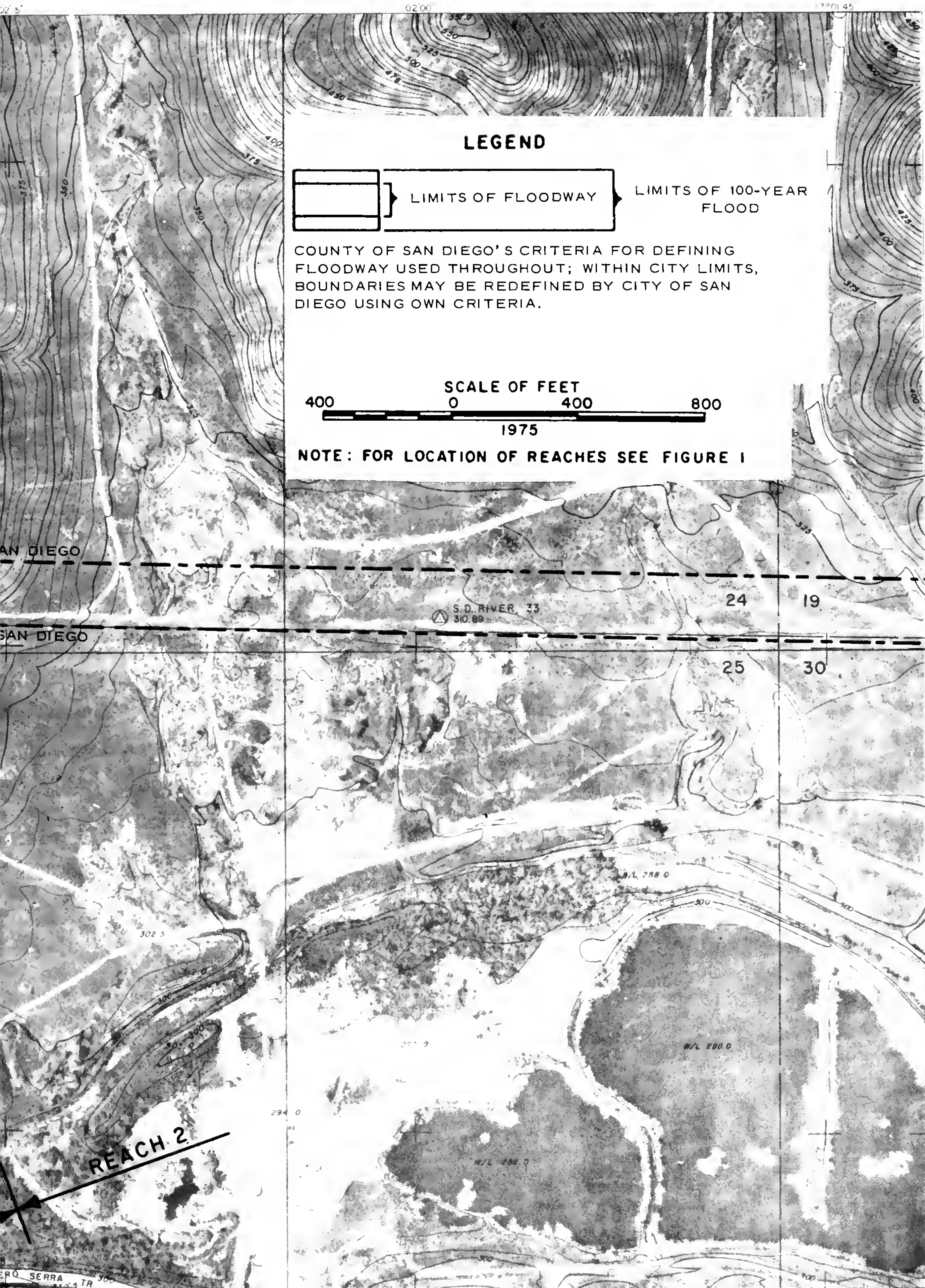


FIGURE 5-AREAS OF POTENTIAL INUNDATION FROM A 100-YEAR



LOOD AND LOCATION OF FLOODWAY - REACHES I AND 2

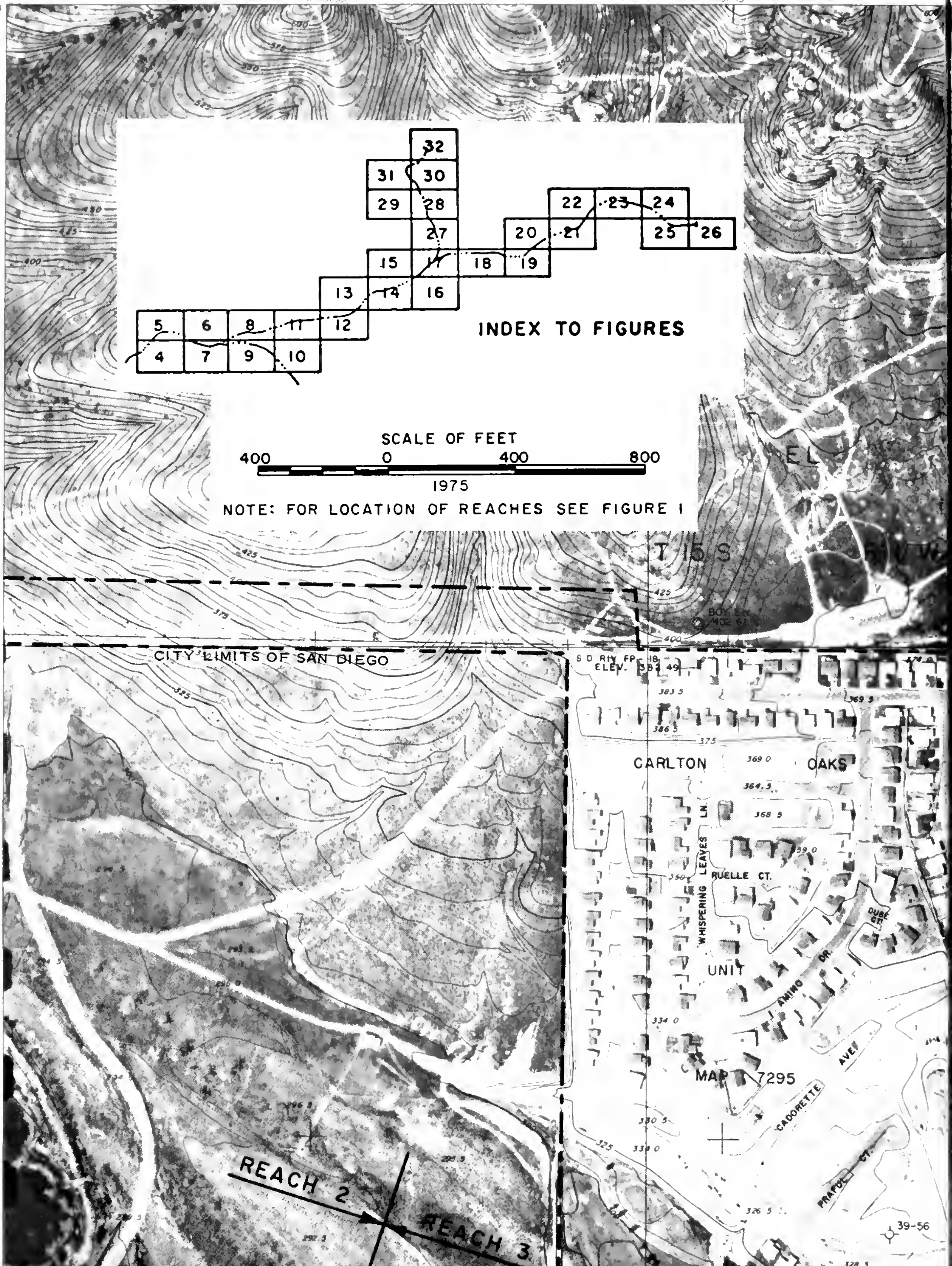
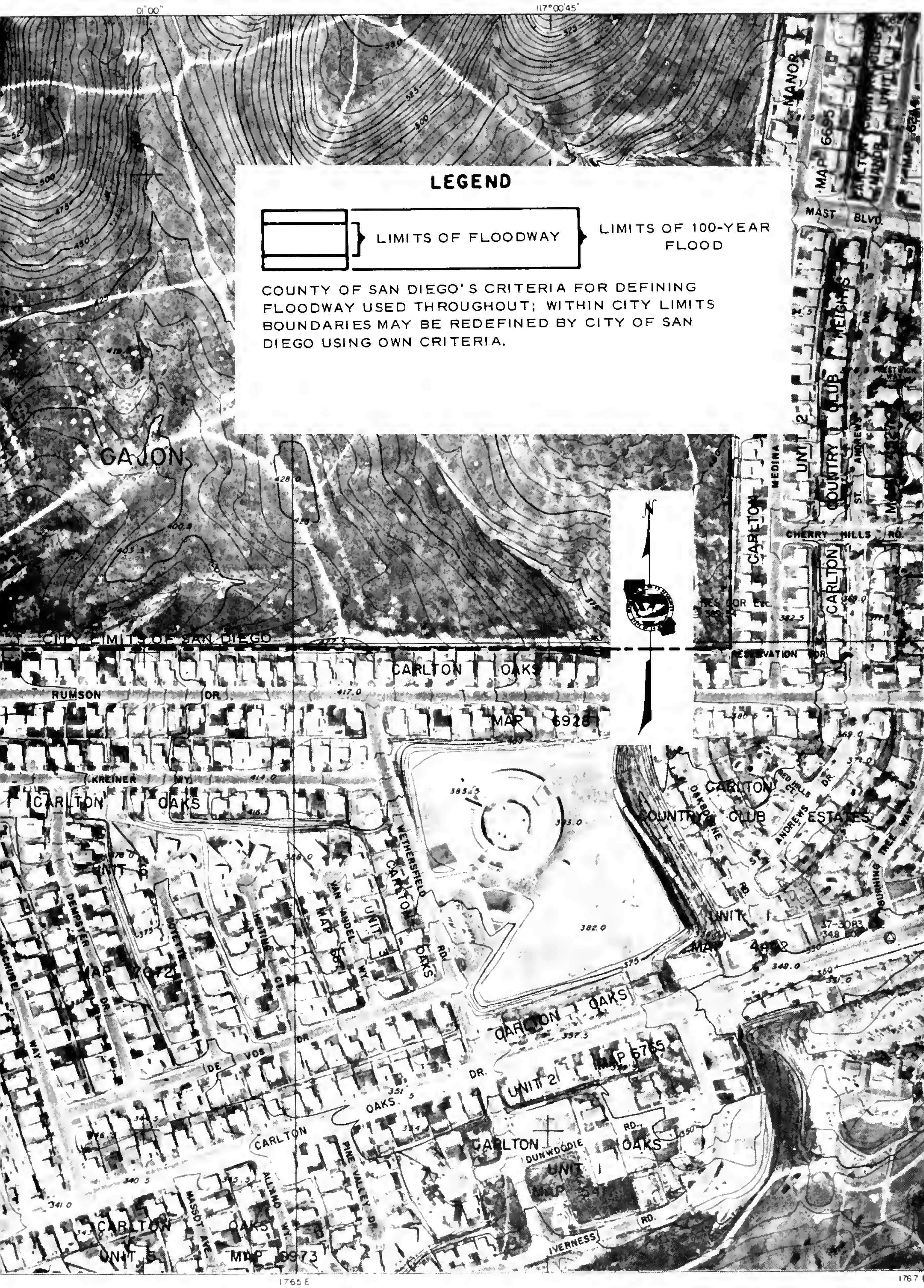


FIGURE 6-AREAS OF POTENTIAL INUNDATION FROM A 100-YEA



FLOOD AND LOCATION OF FLOODWAY–REACHES 2 AND 3

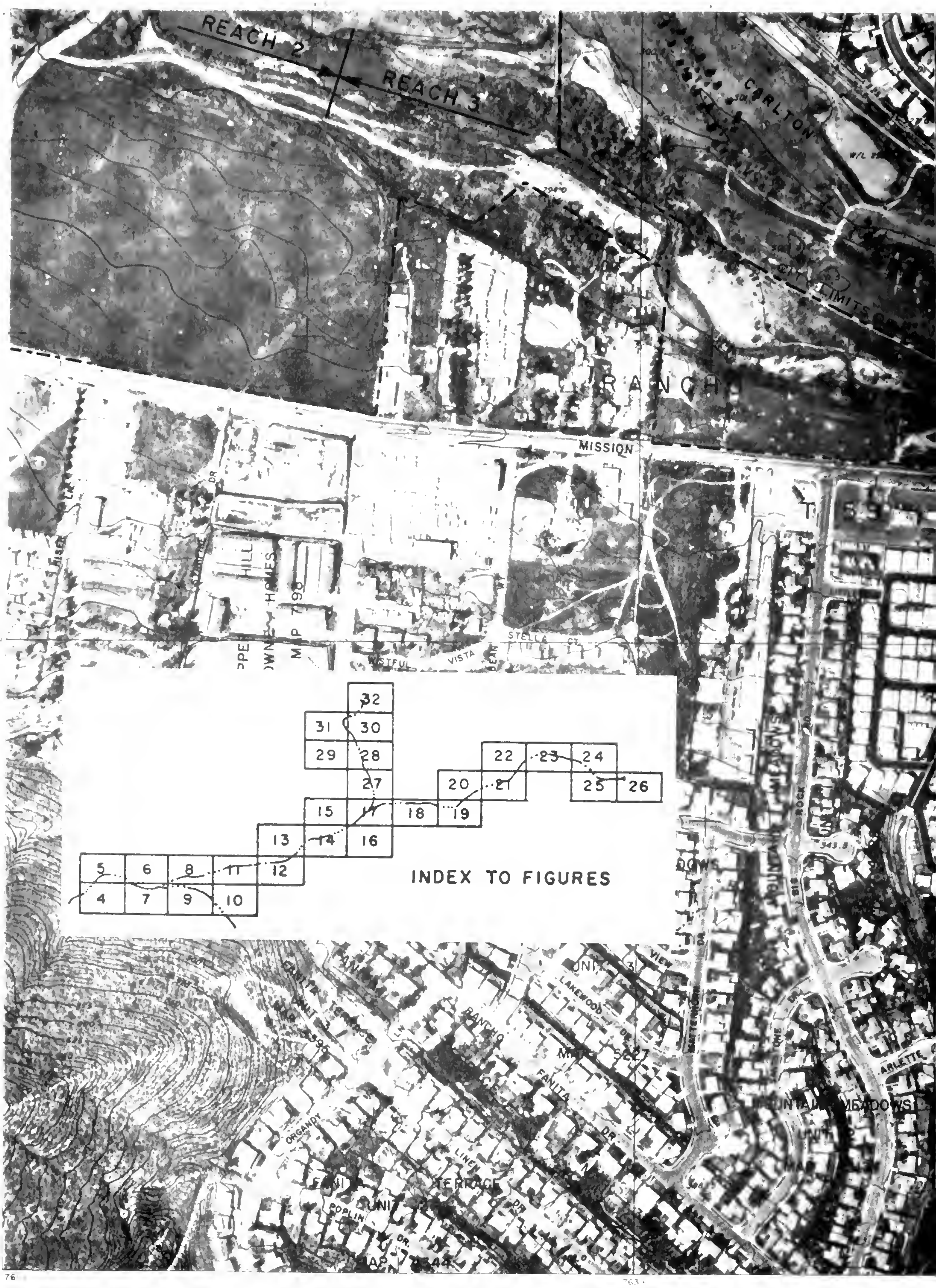


FIGURE 7 - AREAS OF POTENTIAL INUNDATION FROM A 100-YEAR

FLOOD AND LOCATION OF FLOODWAY—REACHES 2 AND 3

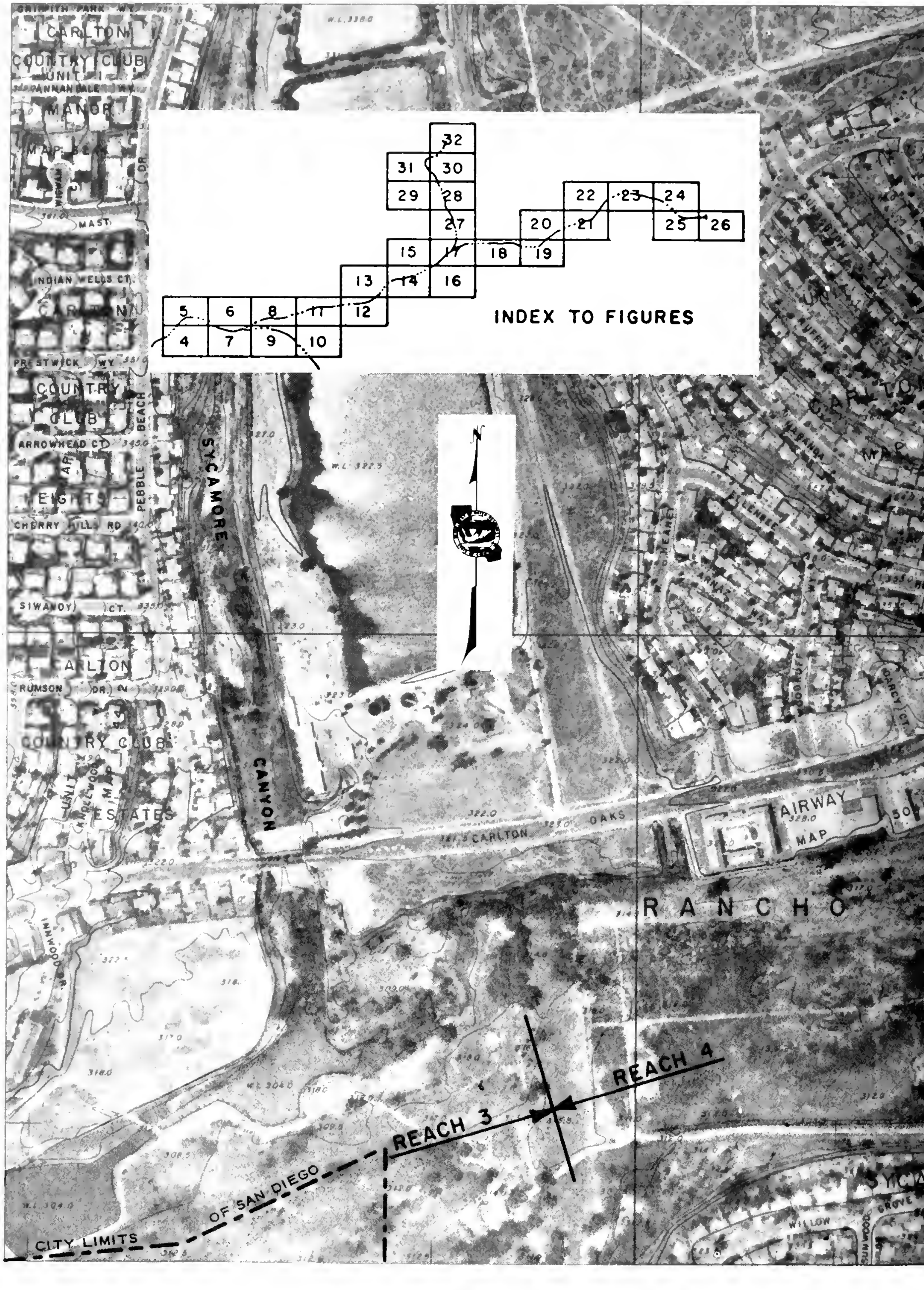
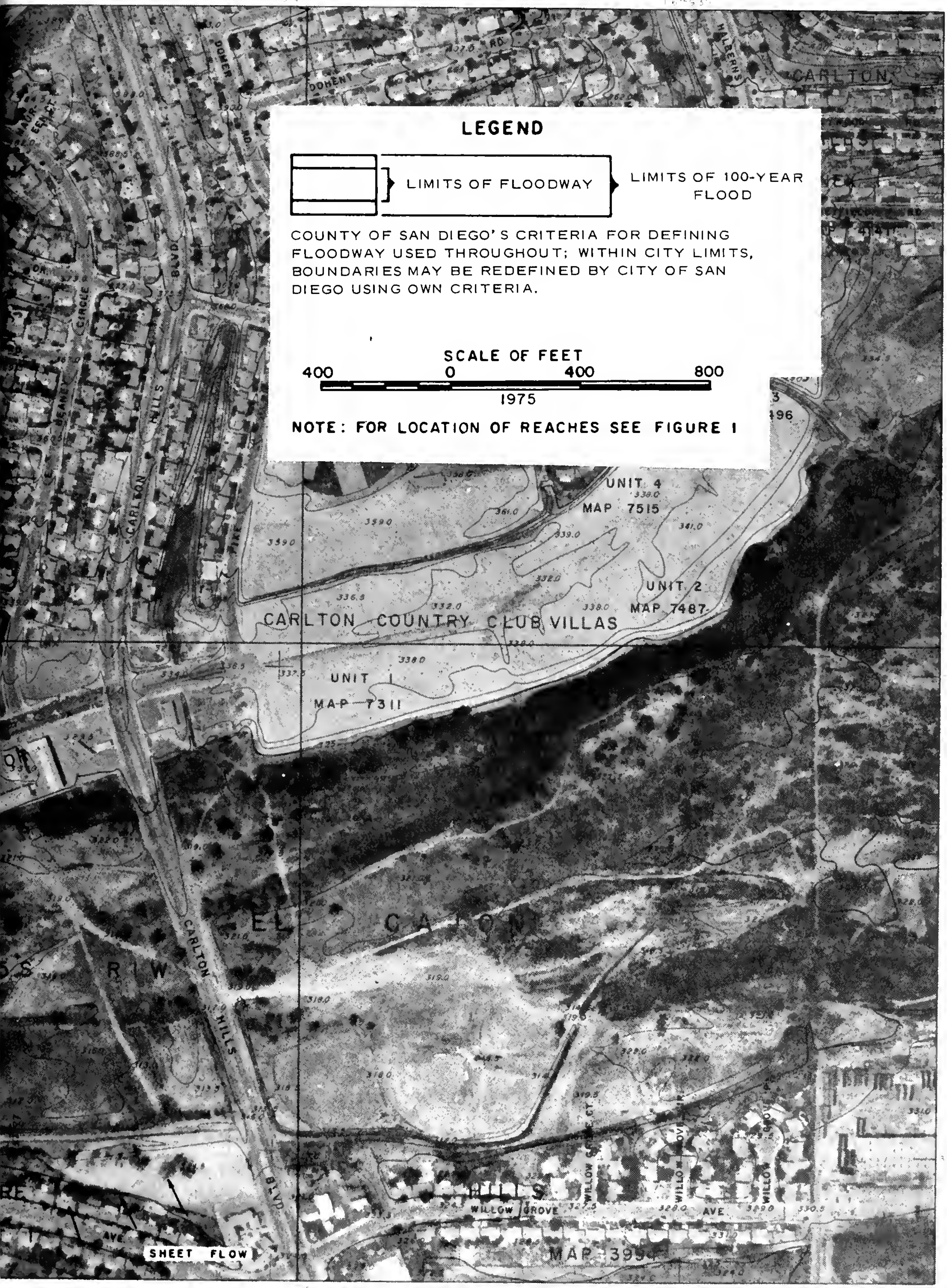


FIGURE 8-AREAS OF POTENTIAL INUNDATION FROM A 100-YEAR



LOOD AND LOCATION OF FLOODWAY - REACHES 3 AND 4

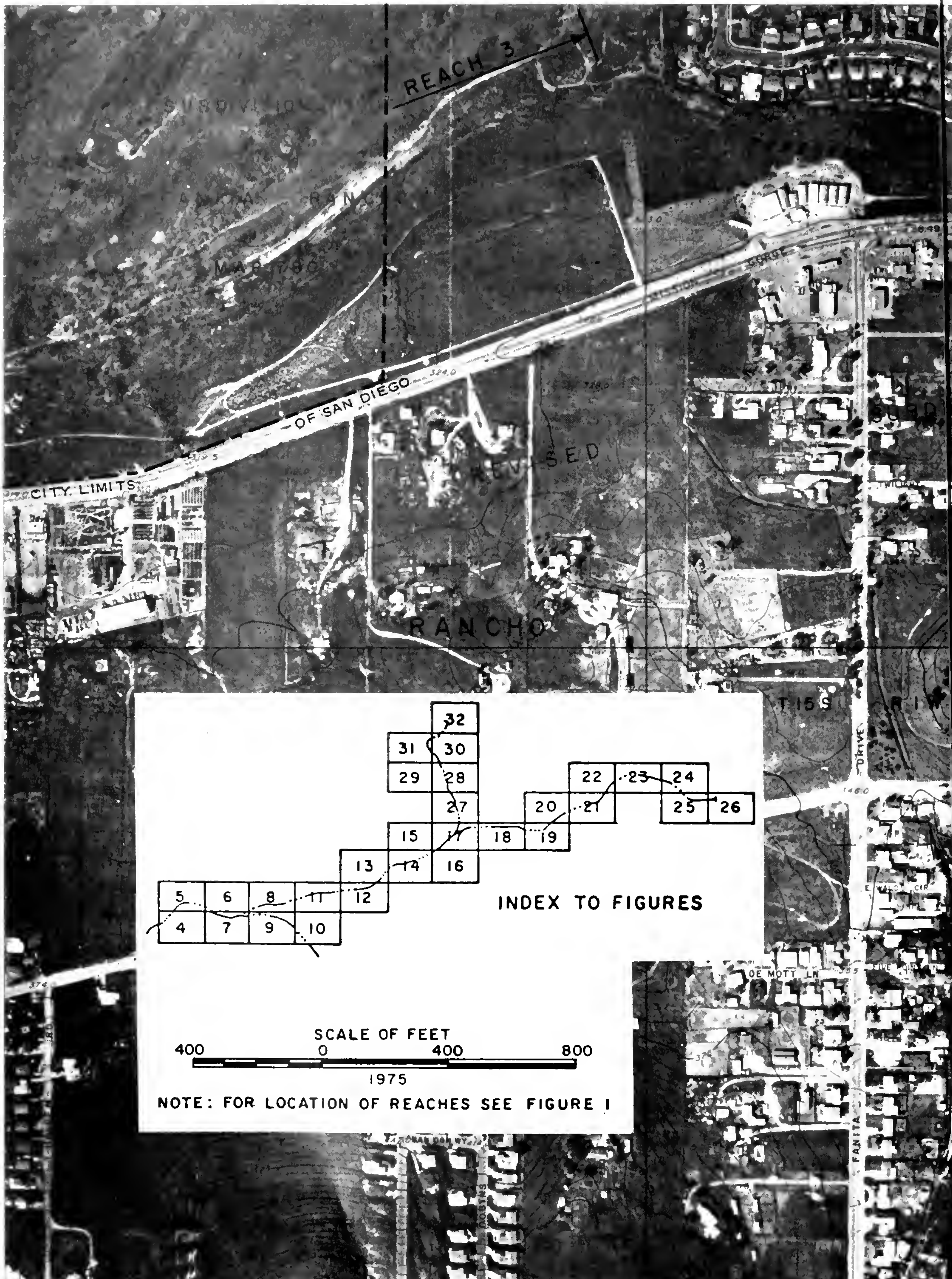
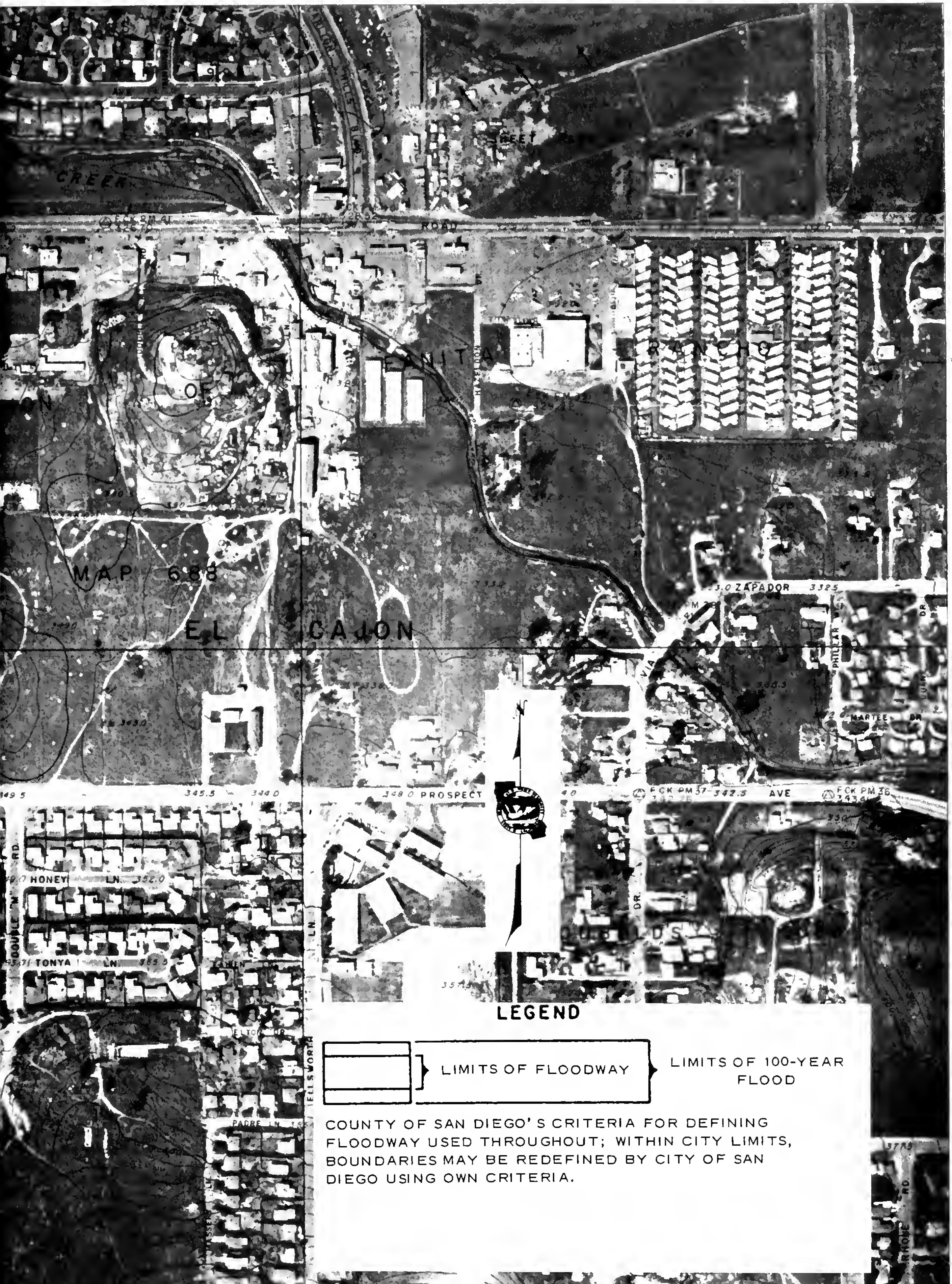
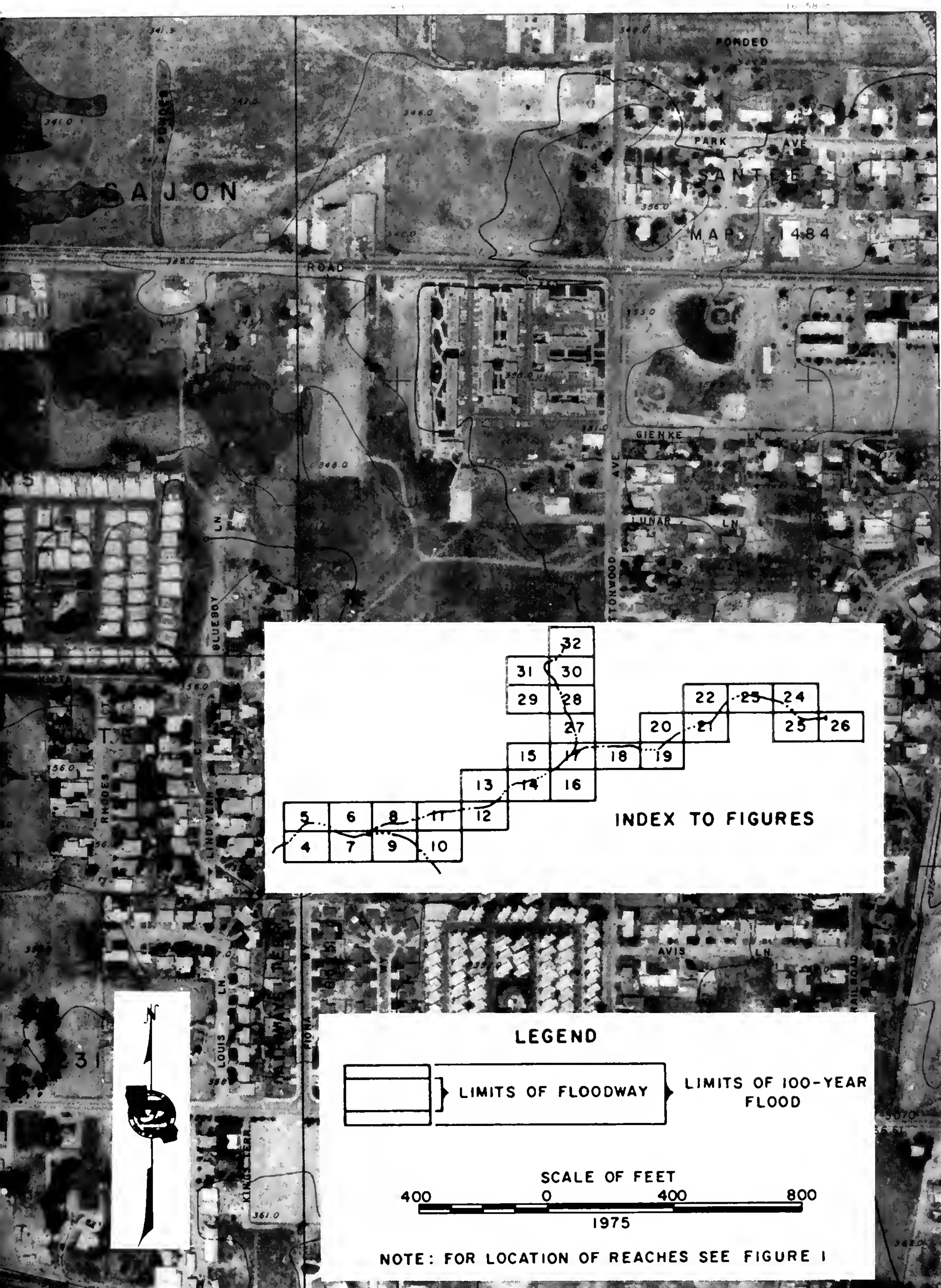


FIGURE 9 - AREAS OF POTENTIAL INUNDATION FROM A 100-YEAR



FLOOD AND LOCATION OF FLOODWAY - REACH 3

FIGURE 10–AREAS OF POTENTIAL INUNDATION FROM A 100-YEAR



FLOOD AND LOCATION OF FLOODWAY - REACH 4

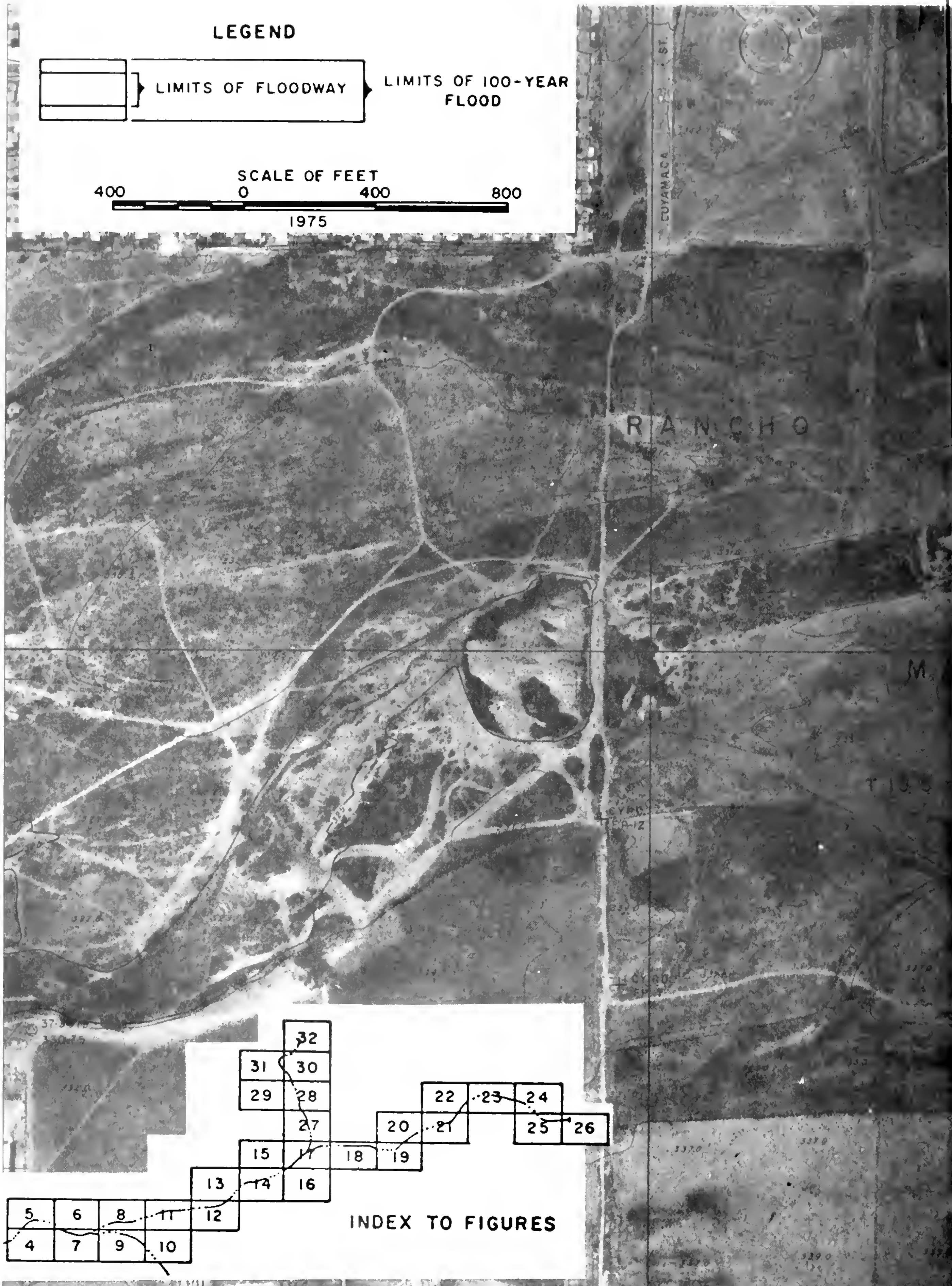


FIGURE 11 - AREAS OF POTENTIAL INUNDATION FROM A 100-YEAR

FLOOD AND LOCATION OF FLOODWAY - REACHES 4 AND 5

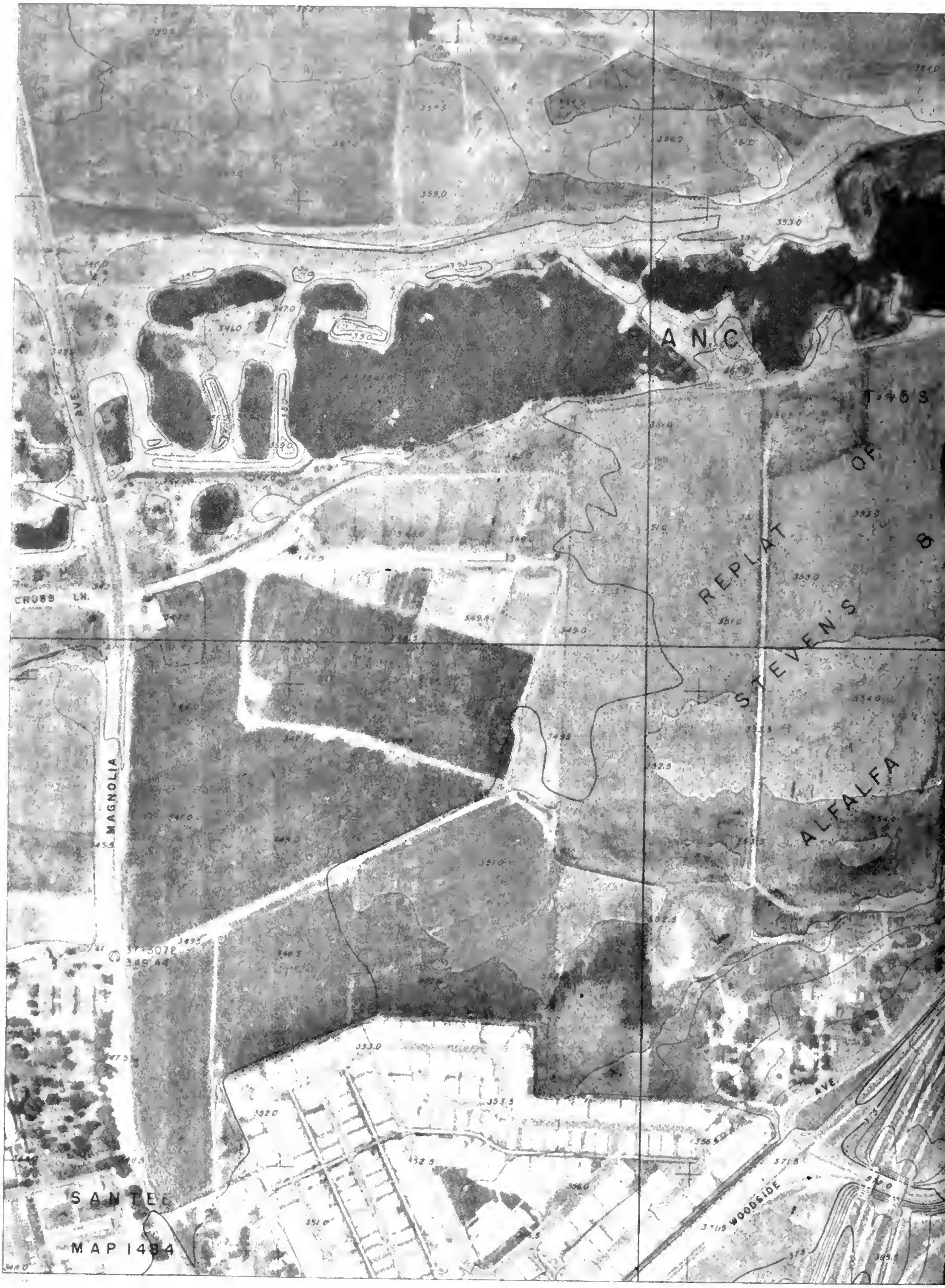
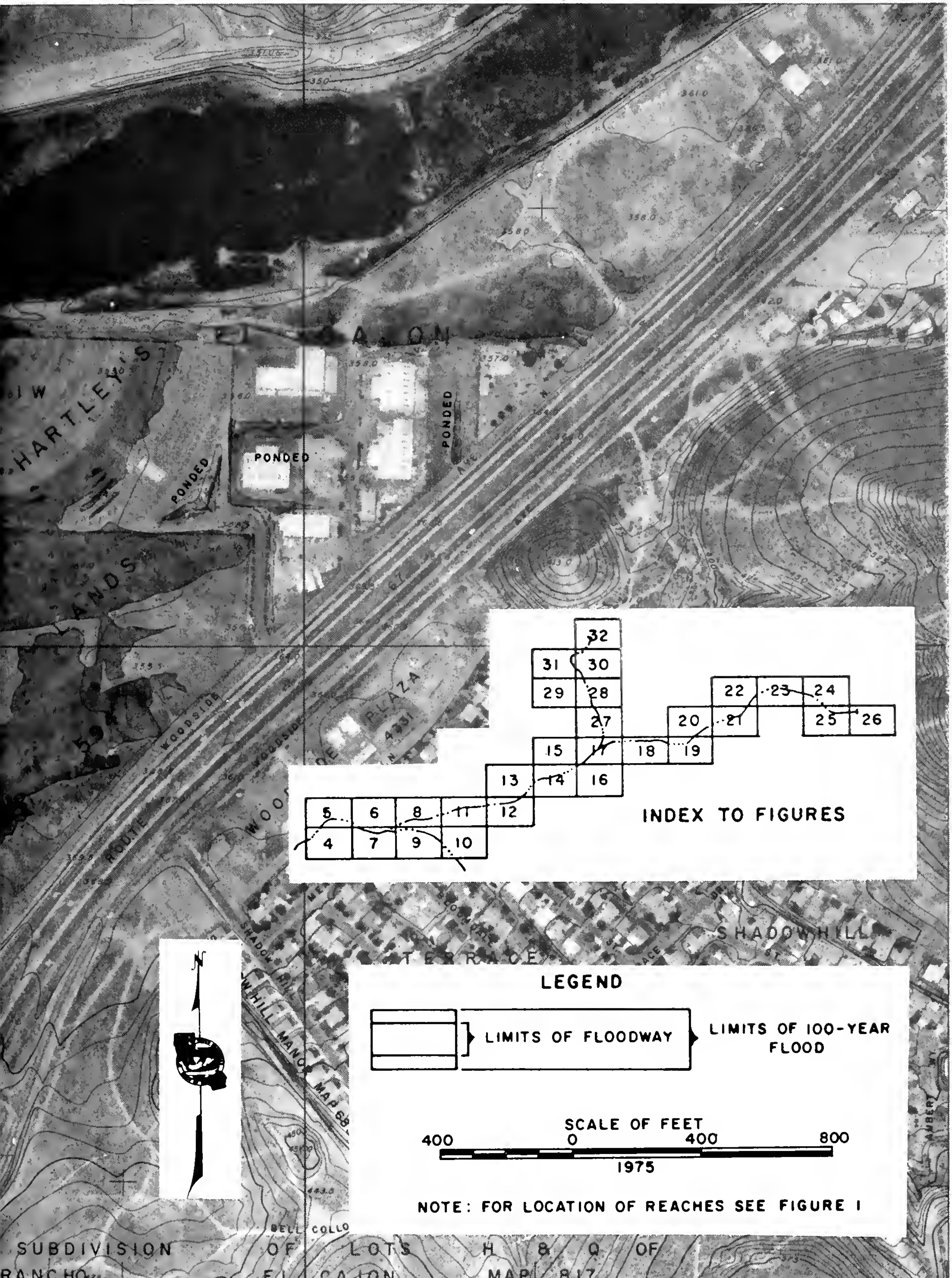


FIGURE 12 - AREAS OF POTENTIAL INUNDATION FROM A 100-YEAR



FLOOD AND LOCATION OF FLOODWAY - REACH 5

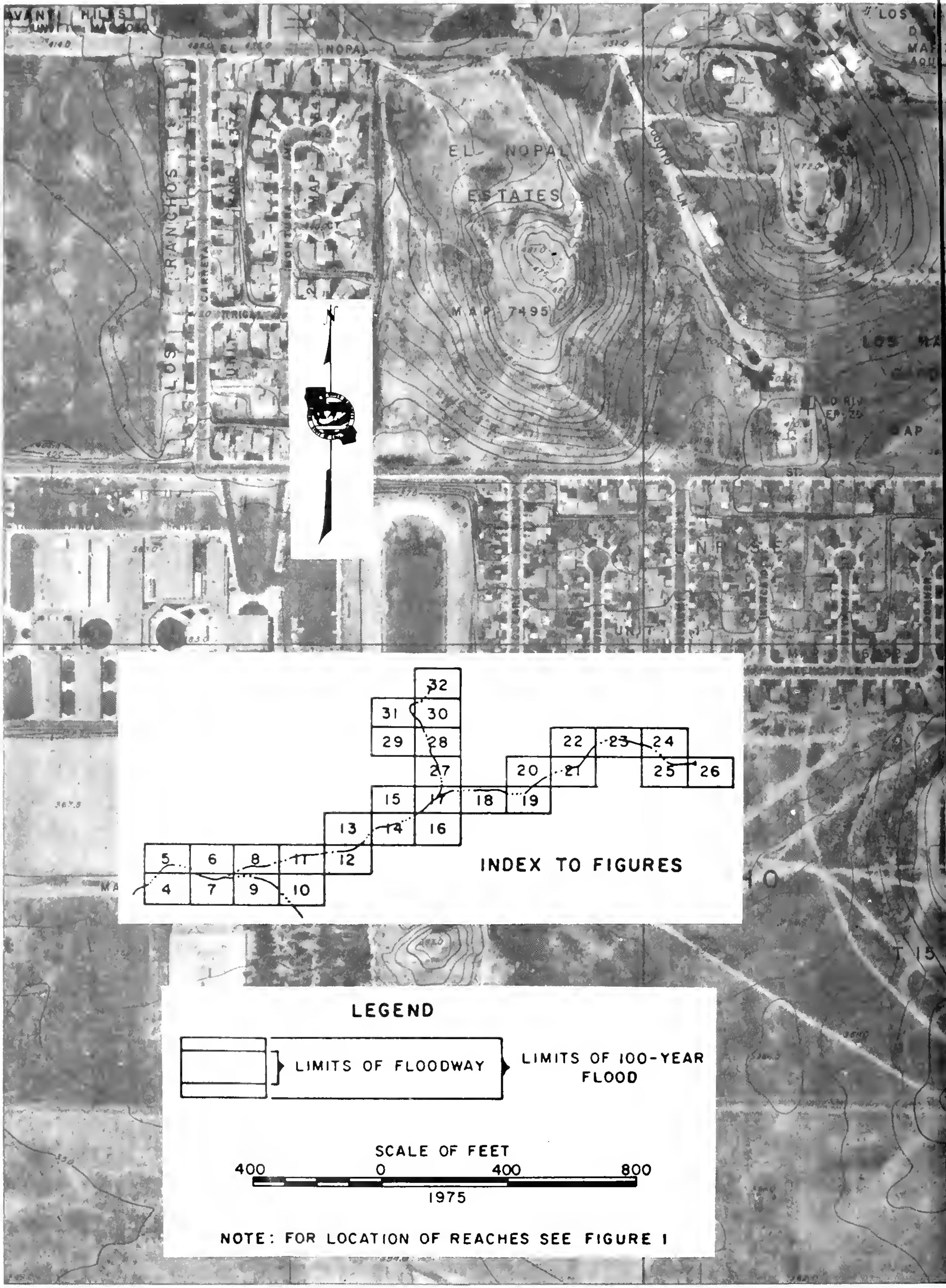
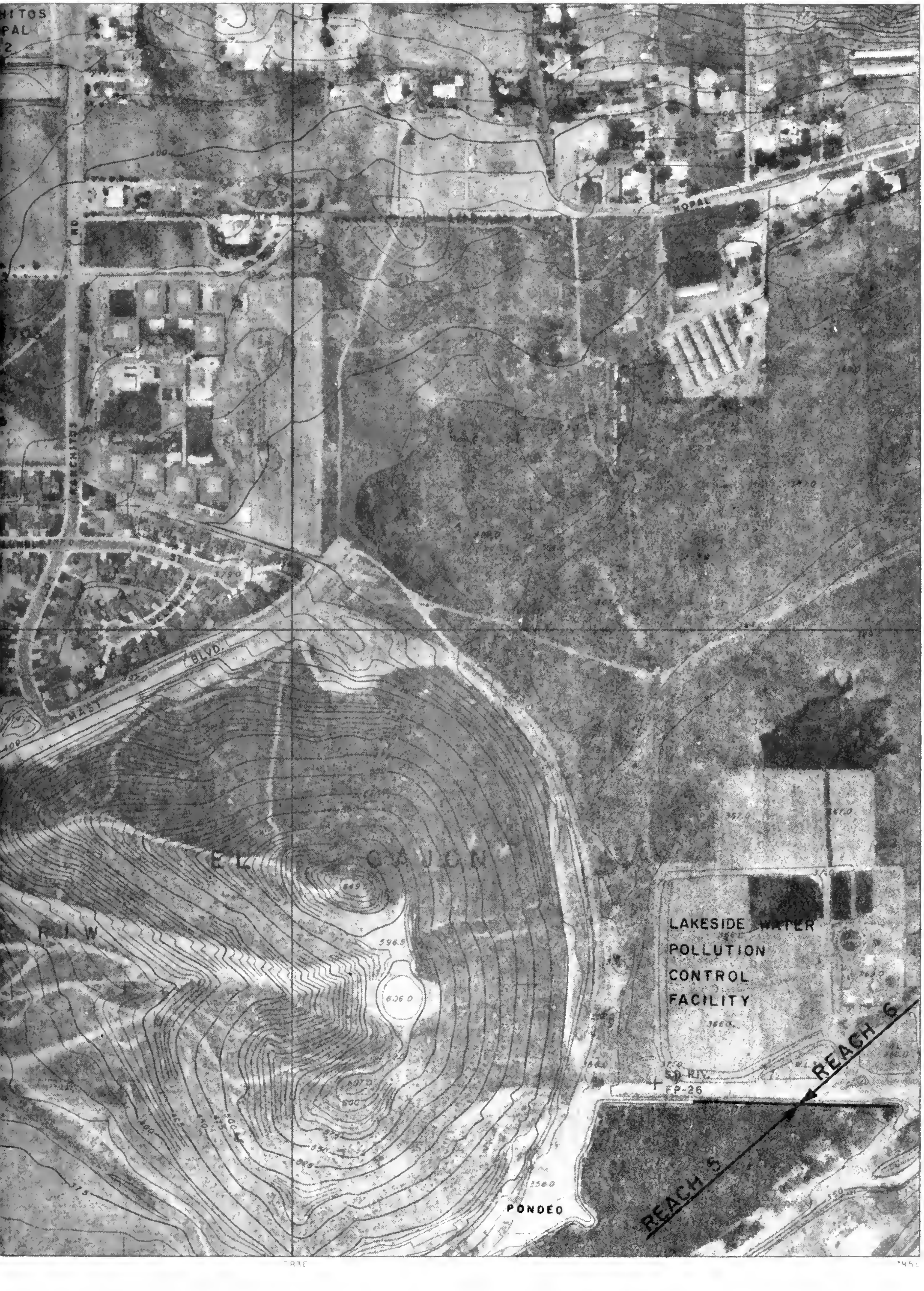


FIGURE 13-AREAS OF POTENTIAL INUNDATION FROM A 100-YEAR



FLOOD AND LOCATION OF FLOODWAY - REACHES 5 AND 6

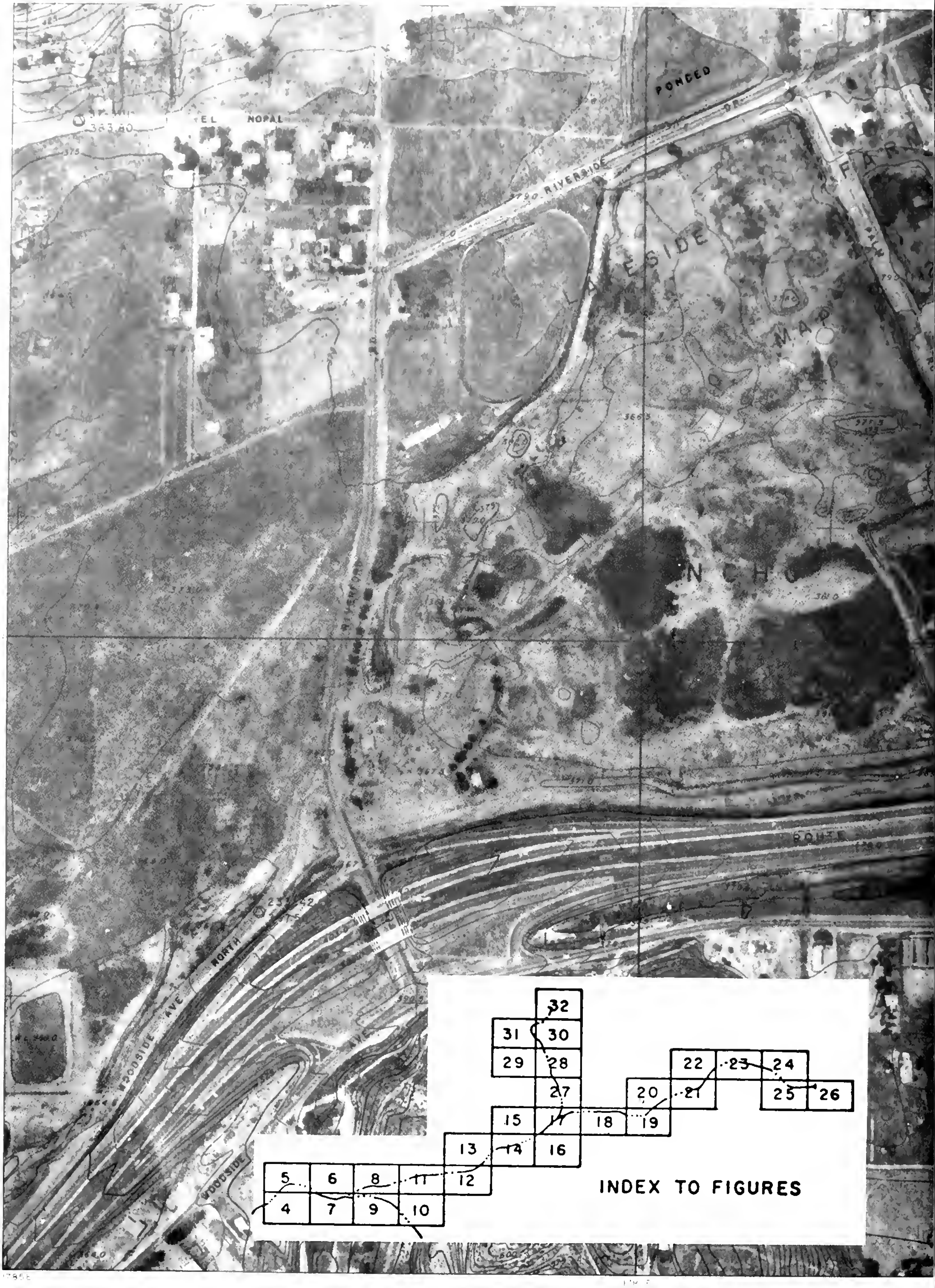
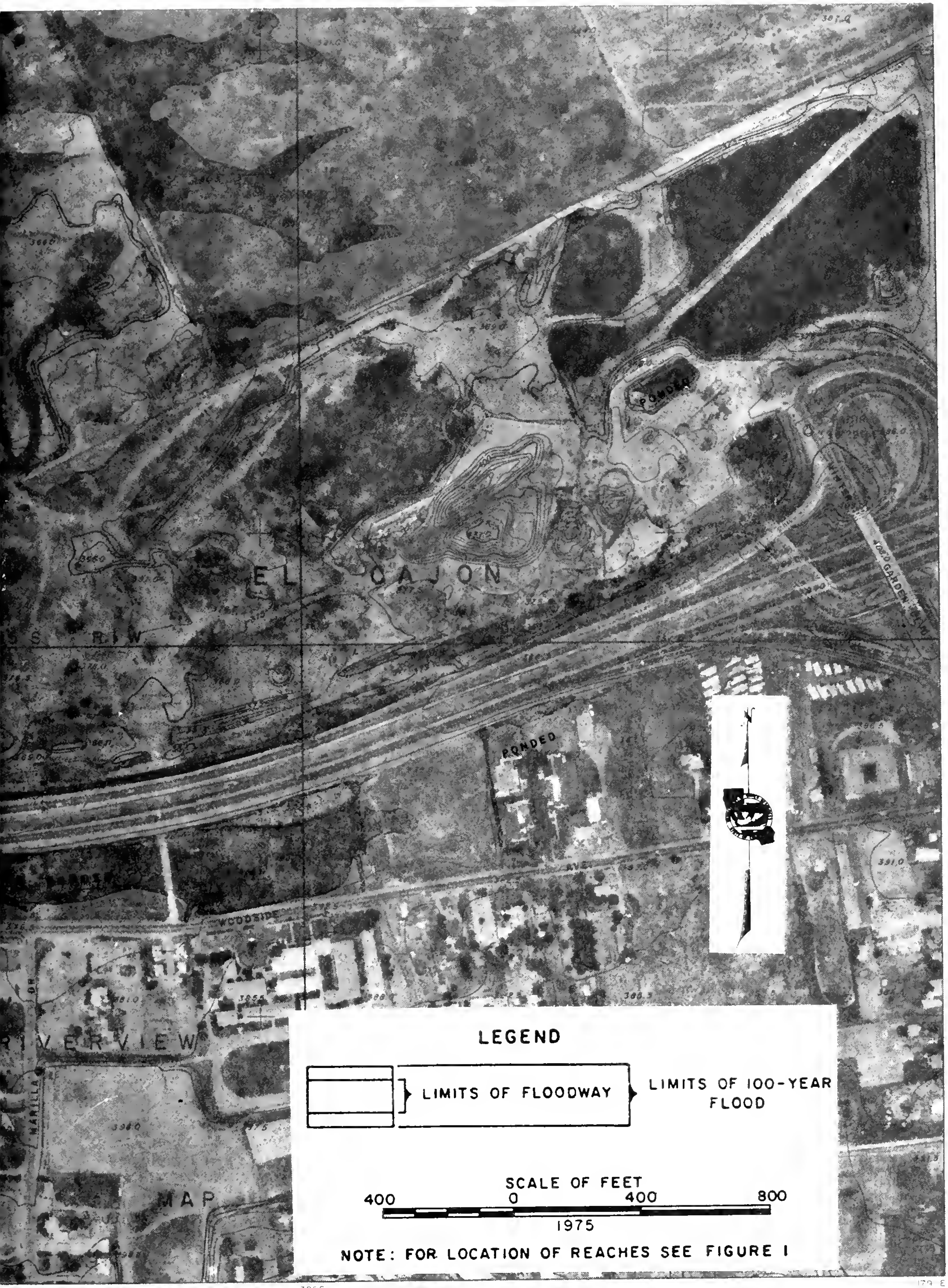
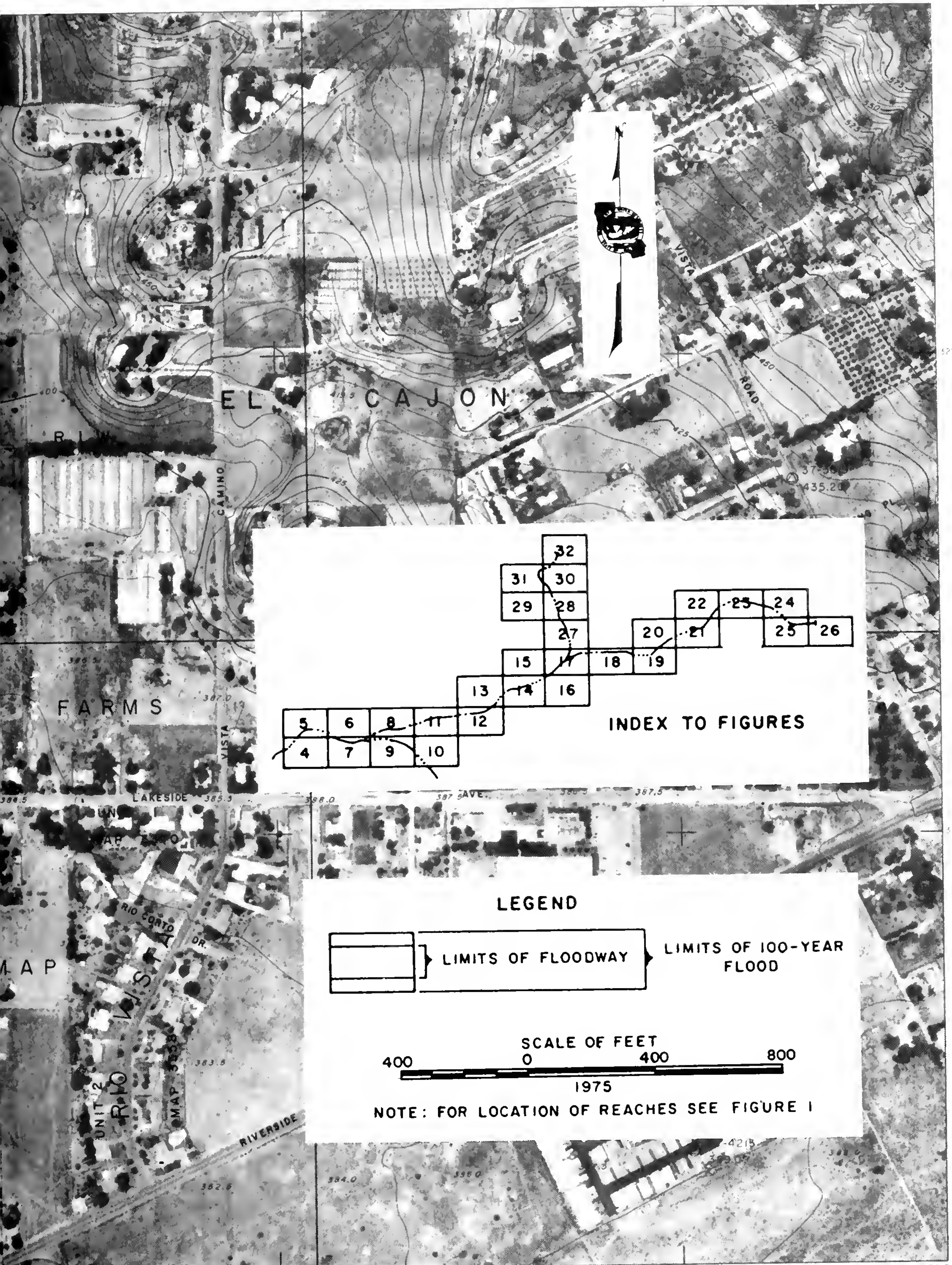


FIGURE 14-AREAS OF POTENTIAL INUNDATION FROM A 100-YEA



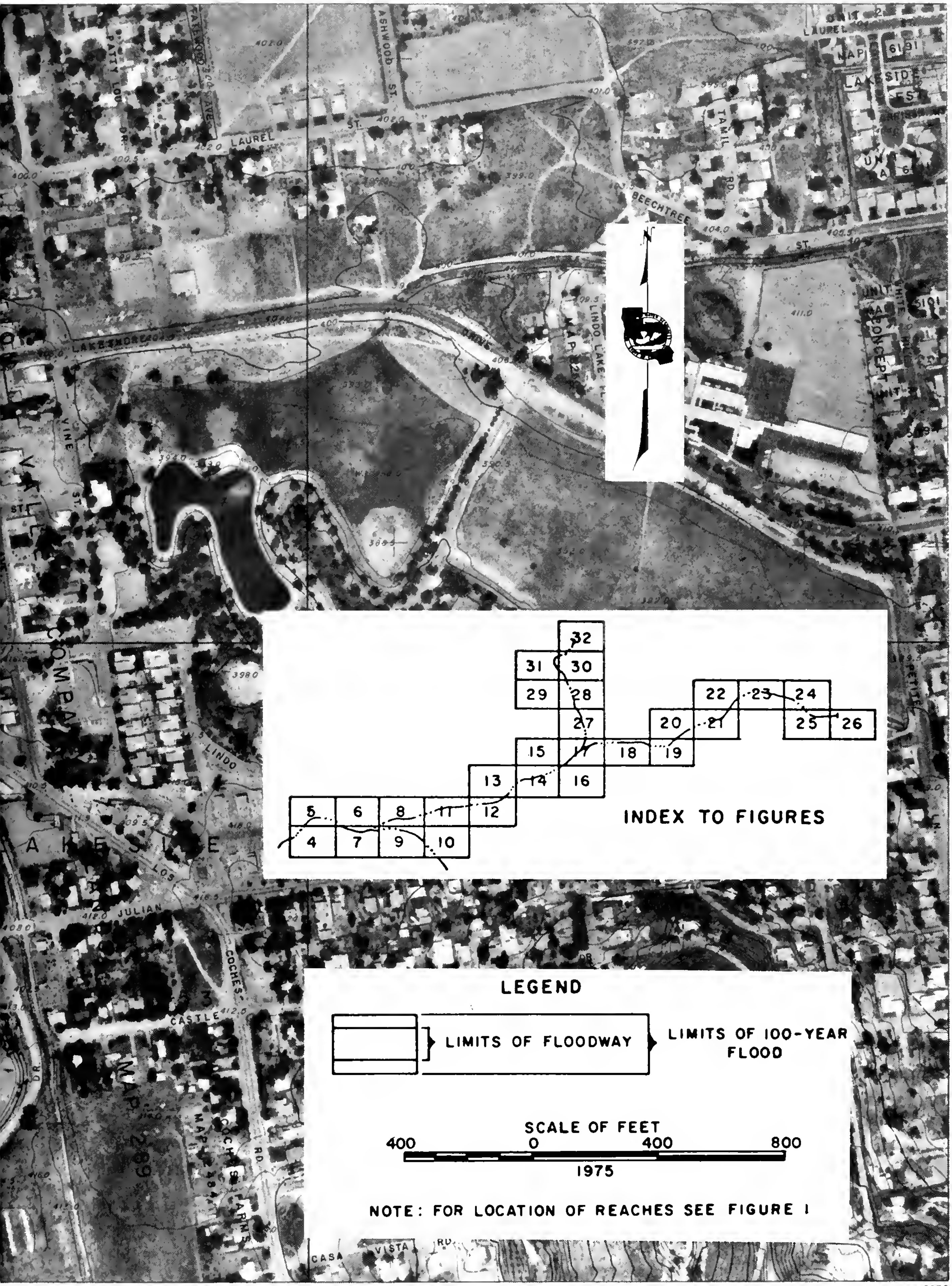
FLOOD AND LOCATION OF FLOODWAY - REACH 6

FIGURE 15-AREAS OF POTENTIAL INUNDATION FROM A 100-YEAR



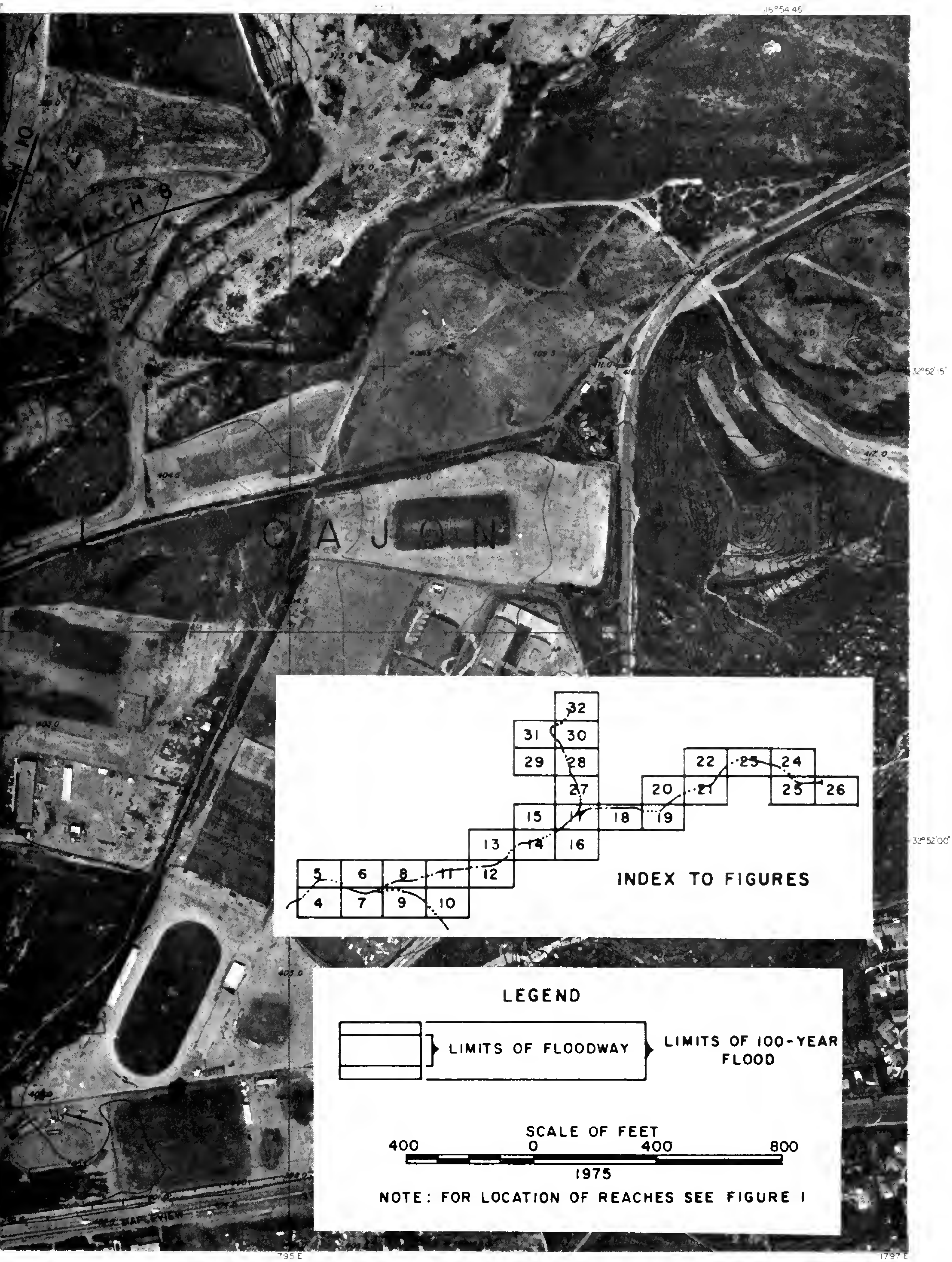
FLOOD AND LOCATION OF FLOODWAY-REACH 6

FIGURE 16-AREAS OF POTENTIAL INUNDATION FROM A 100-YEAR



FLOOD AND LOCATION OF FLOODWAY - REACH 6

 FIGURE 17-AREAS OF POTENTIAL INUNDATION FROM A 100-YEAR



LOOD AND LOCATION OF FLOODWAY-REACHES 6,7, 8 AND 10

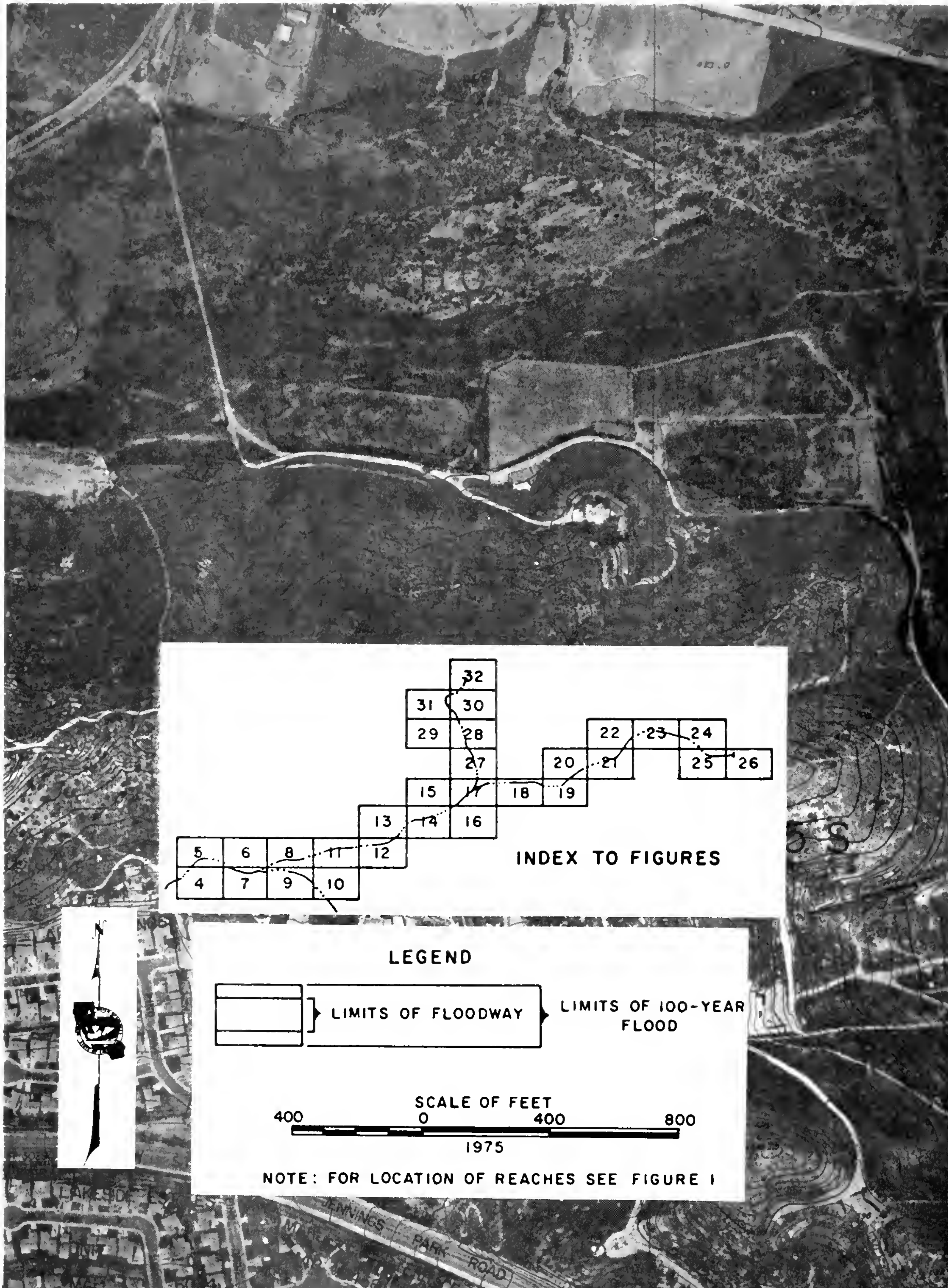
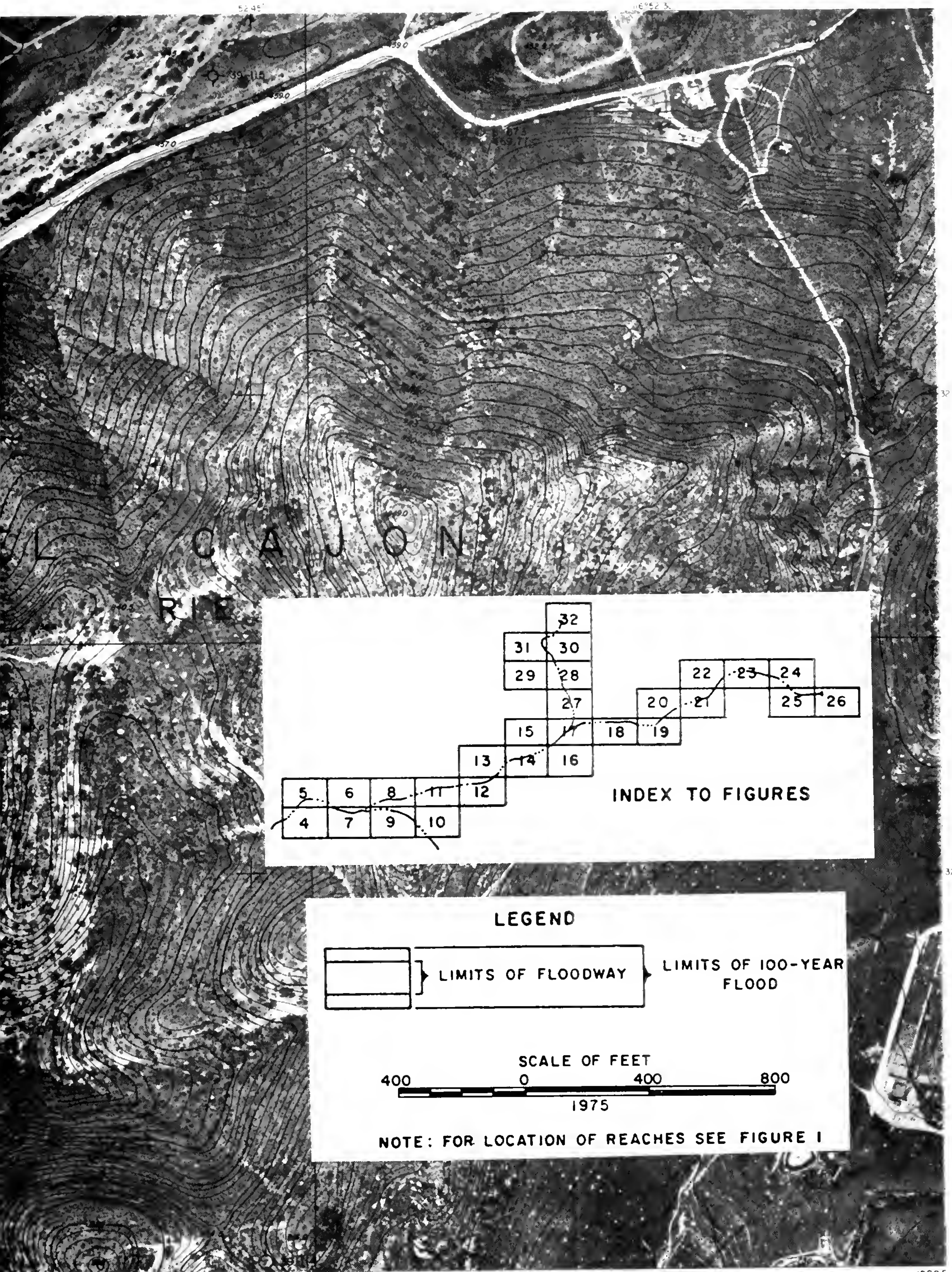


FIGURE 18-AREAS OF POTENTIAL INUNDATION FROM A 100-YEA

FLOOD AND LOCATION OF FLOODWAY - REACH 8

FIGURE 19 - AREAS OF POTENTIAL INUNDATION FROM A 100-YEAR



FLOOD AND LOCATION OF FLOODWAY-REACH 8

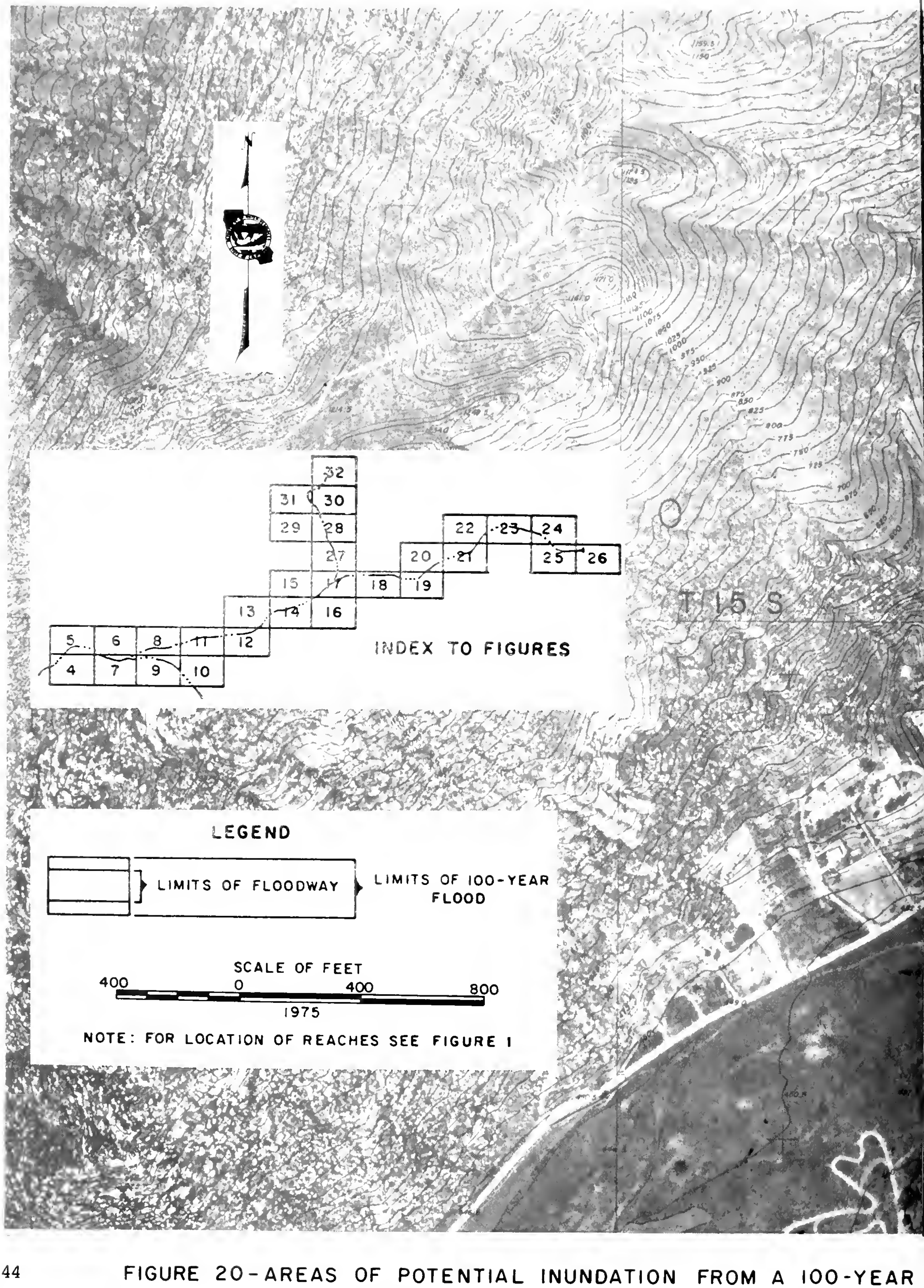
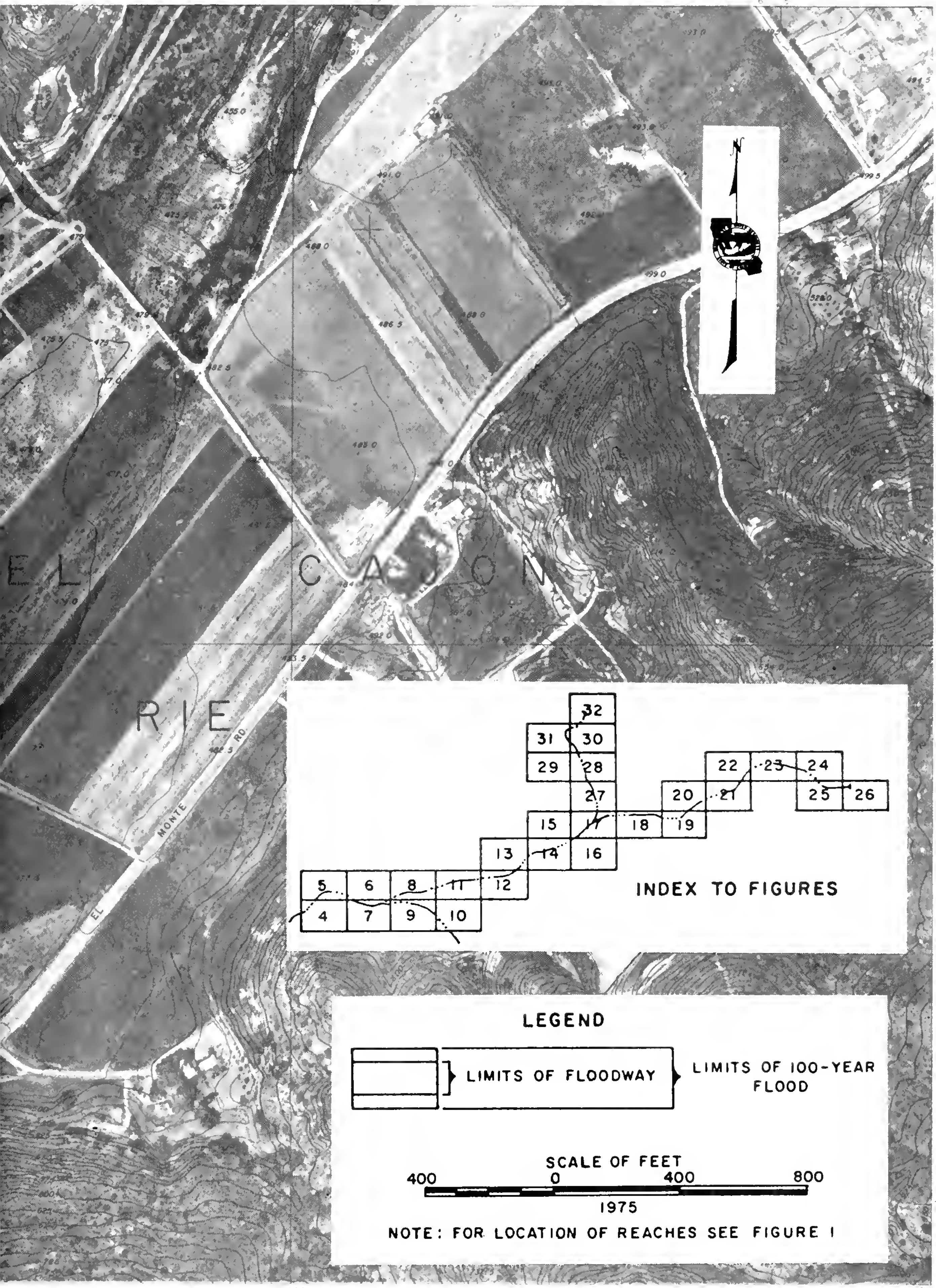


FIGURE 20-AREAS OF POTENTIAL INUNDATION FROM A 100-YEAR

FLOOD AND LOCATION OF FLOODWAY - REACH 8

46 FIGURE 21-AREAS OF POTENTIAL INUNDATION FROM A 100-YEAR



LOOD AND LOCATION OF FLOODWAY-REACH 8

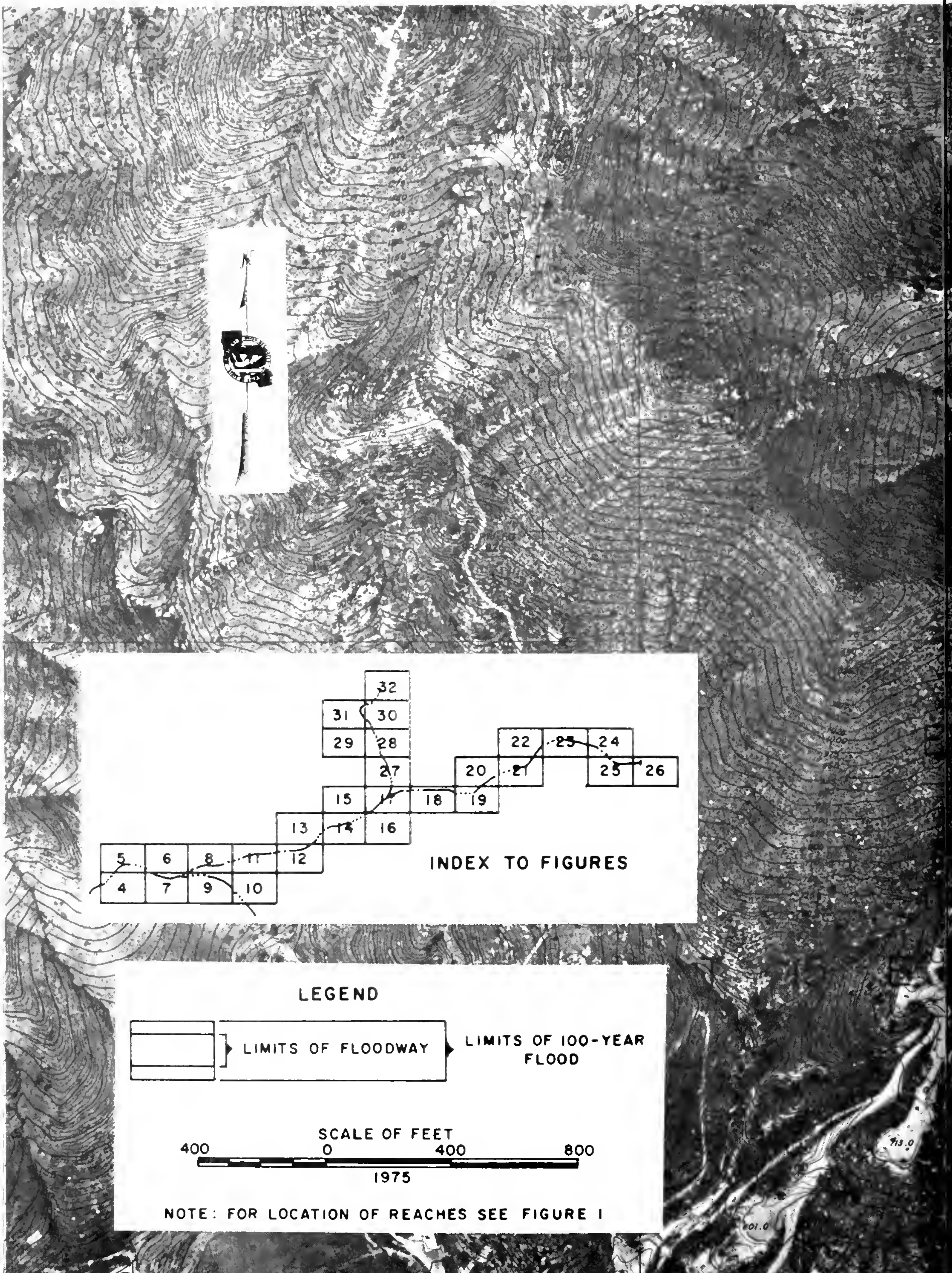


FIGURE 22-AREAS OF POTENTIAL INUNDATION FROM A 100-YEAR F

LOOD AND LOCATION OF FLOODWAY-REACH 8

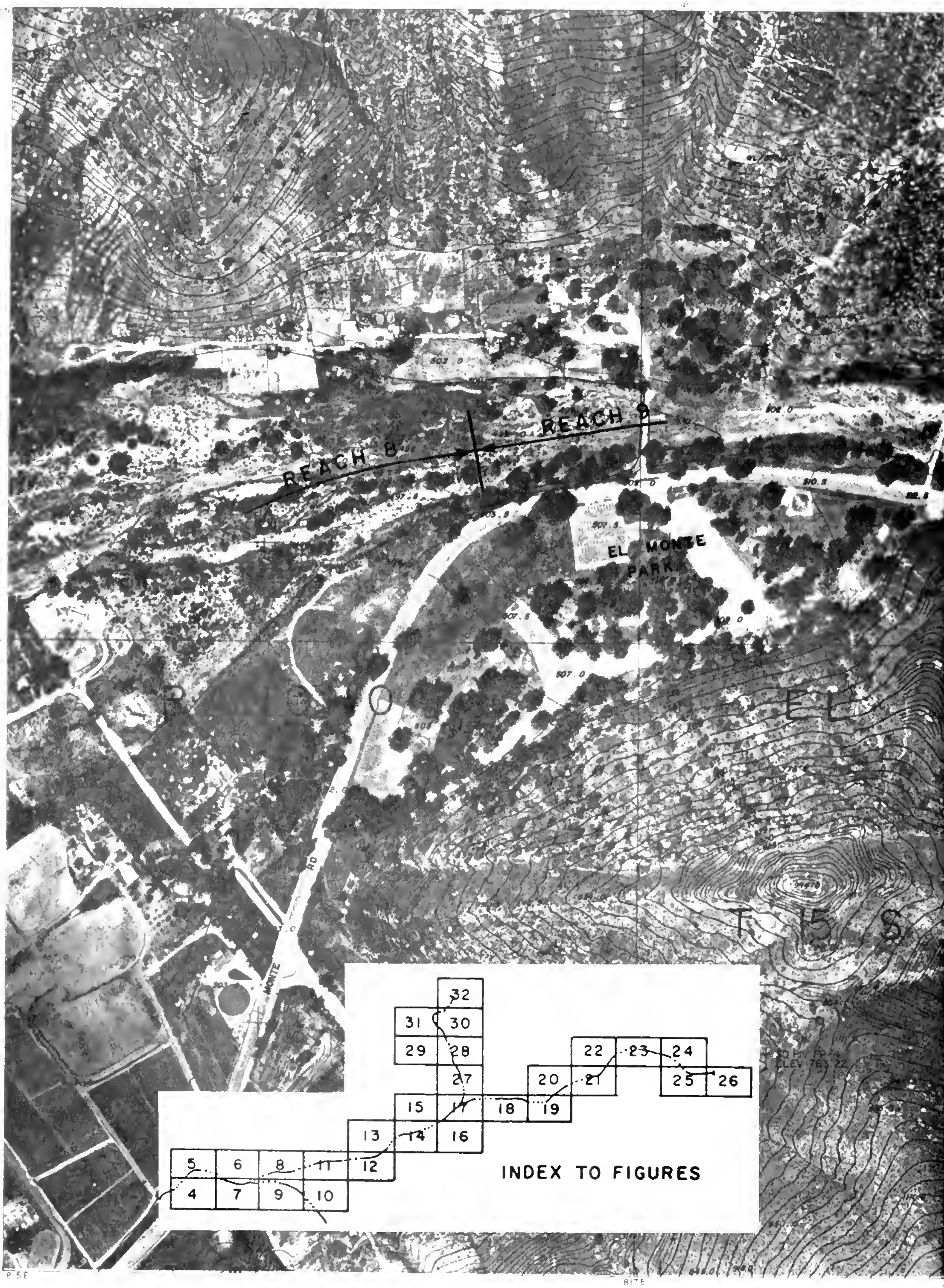
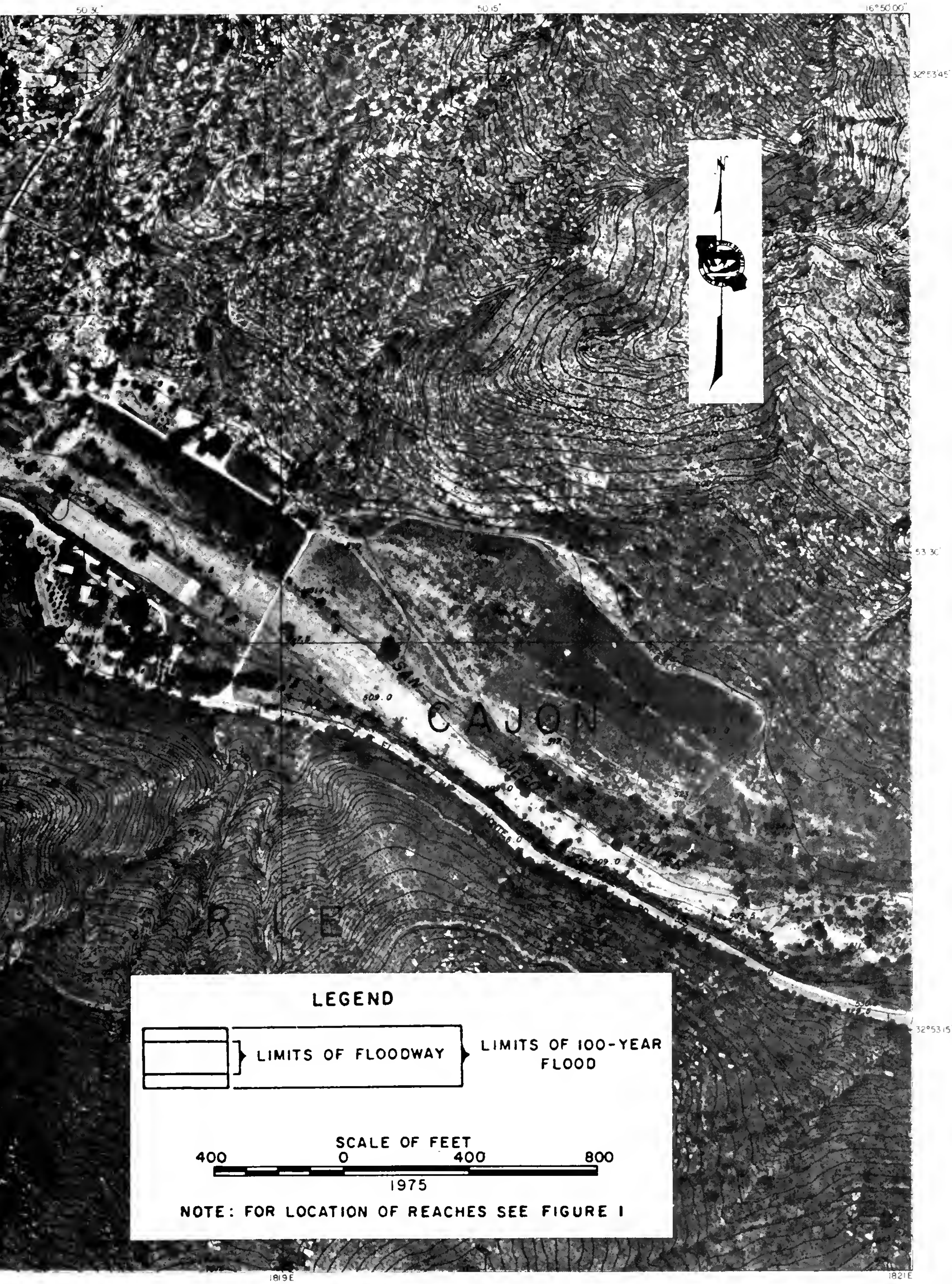
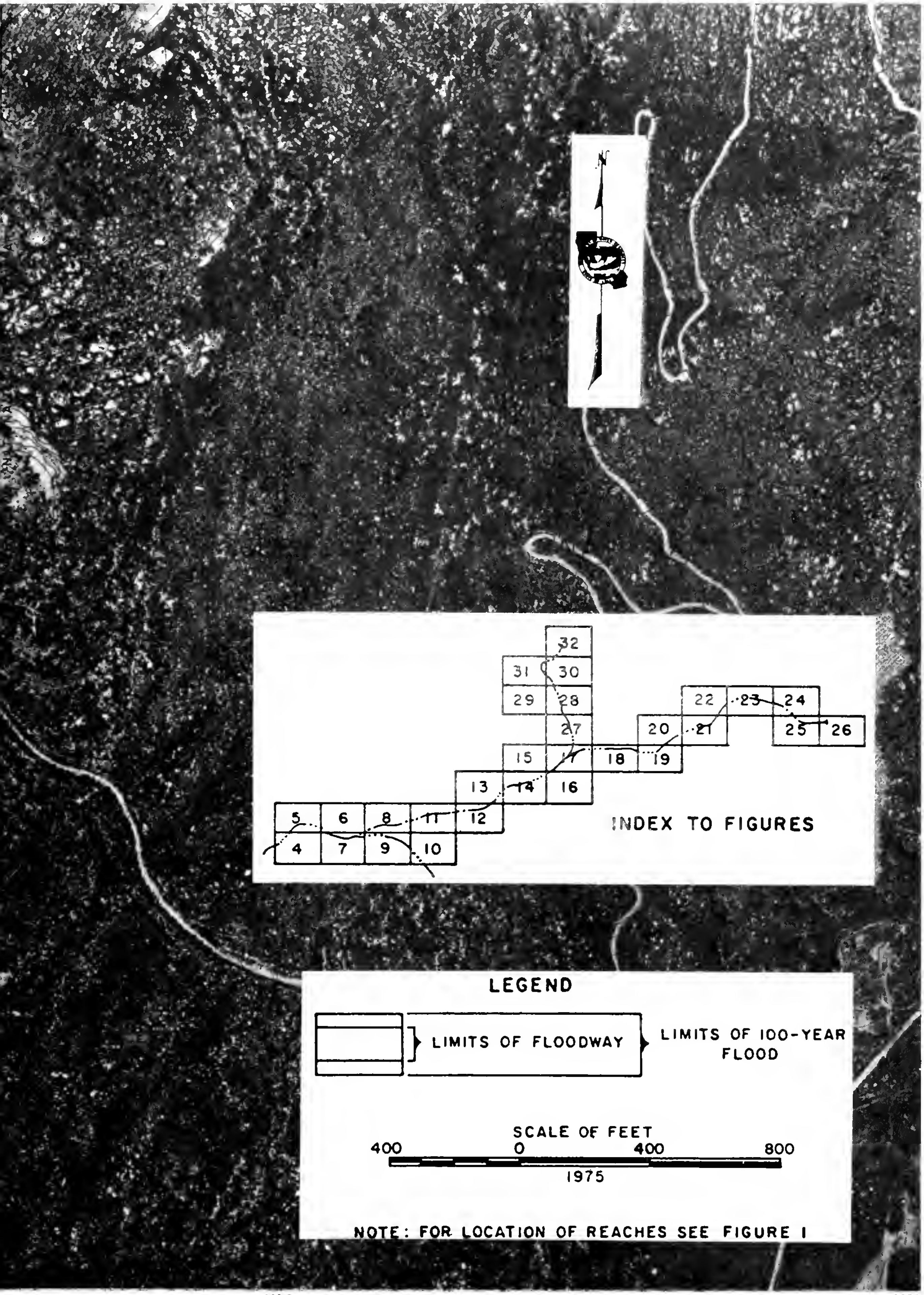


FIGURE 23-AREAS OF POTENTIAL INUNDATION FROM A 100-YEAR FL



.LOOD AND LOCATION OF FLOODWAY - REACHES 8 AND 9

FIGURE 24-AREAS OF POTENTIAL INUNDATION FROM A 100-YEAR



OOD AND LOCATION OF FLOODWAY - REACH 9

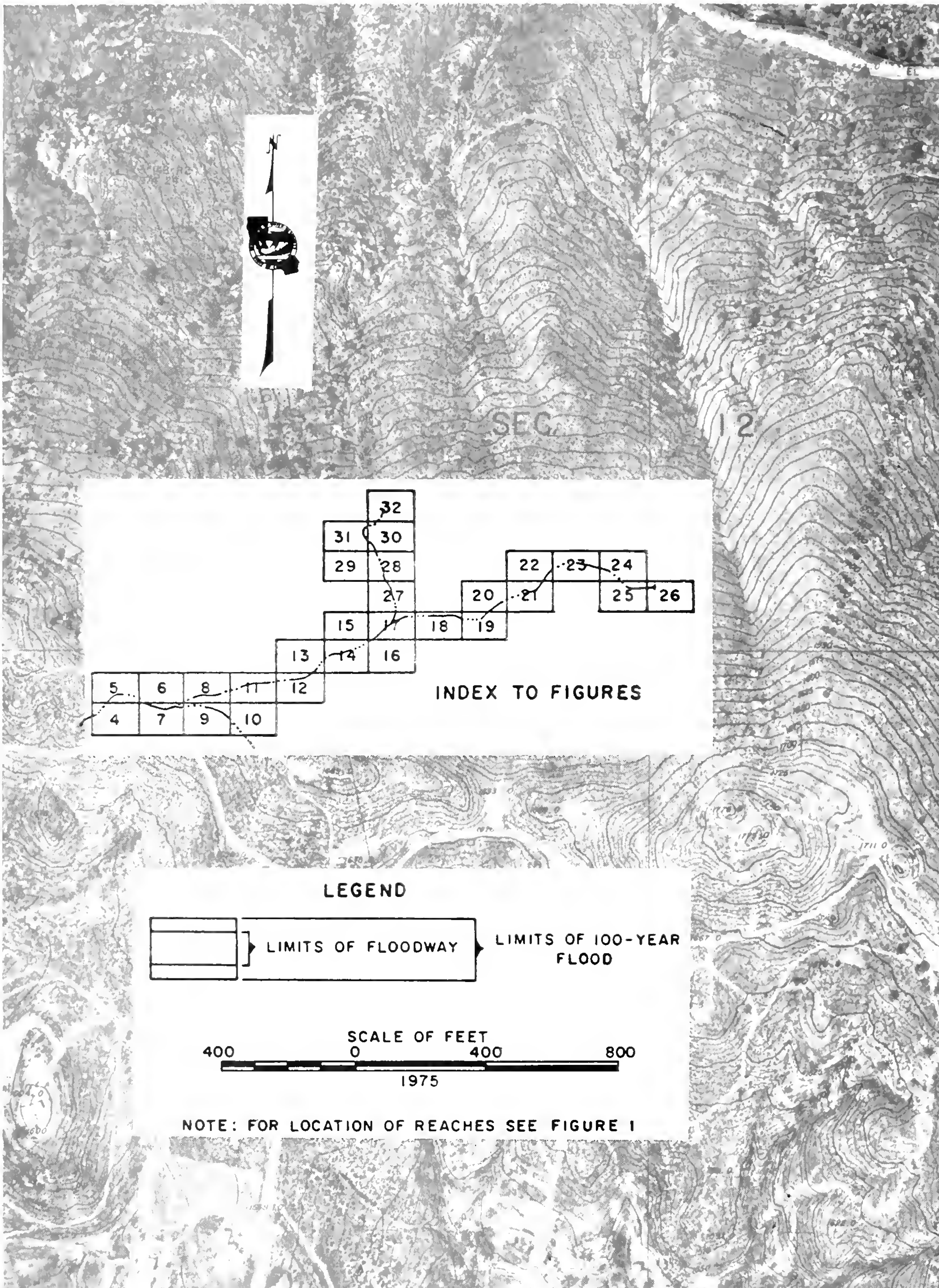


FIGURE 25-AREAS OF POTENTIAL INUNDATION FROM A 100-YEA

LOOD AND LOCATION OF FLOODWAY-REACH 9

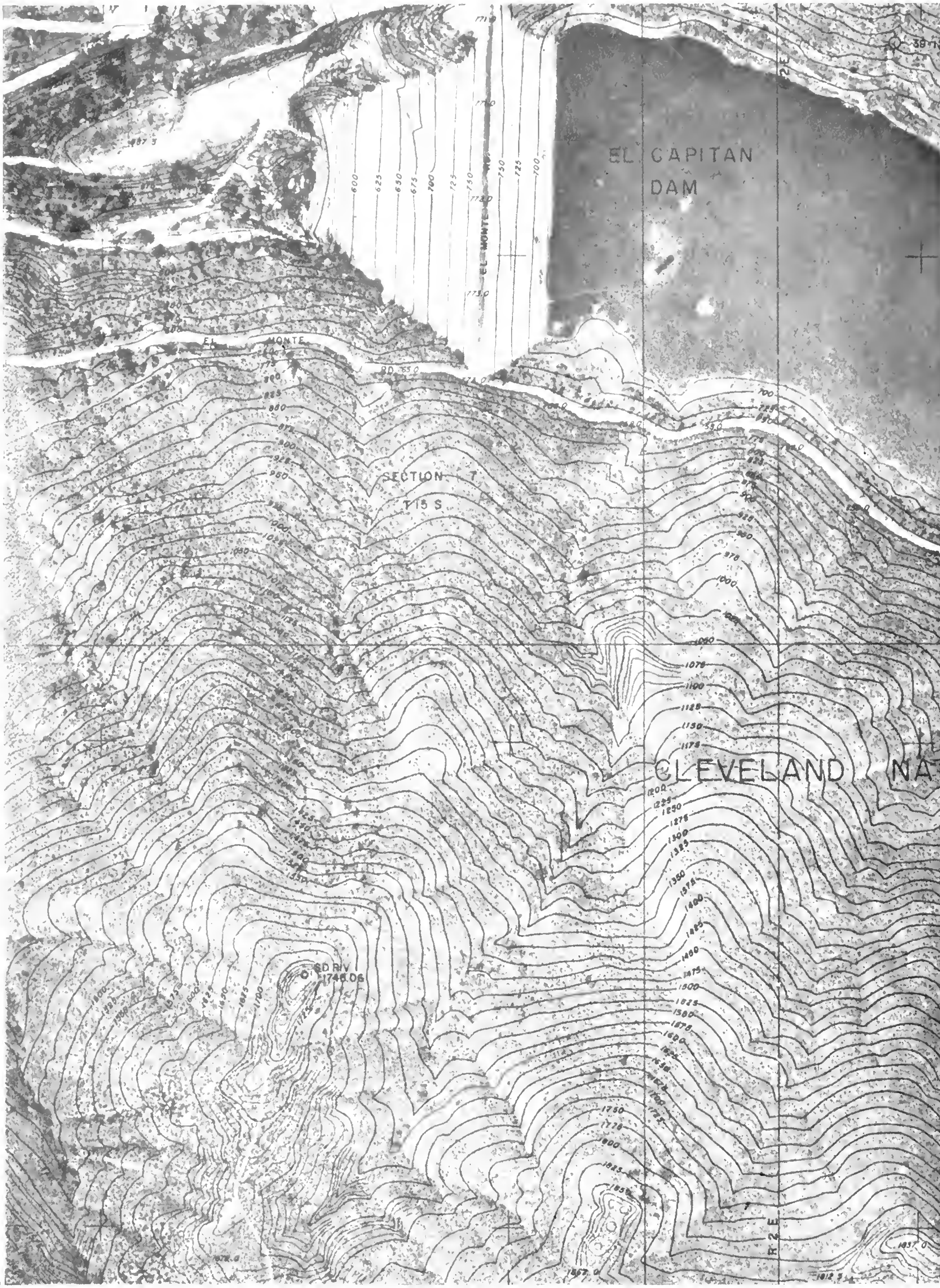
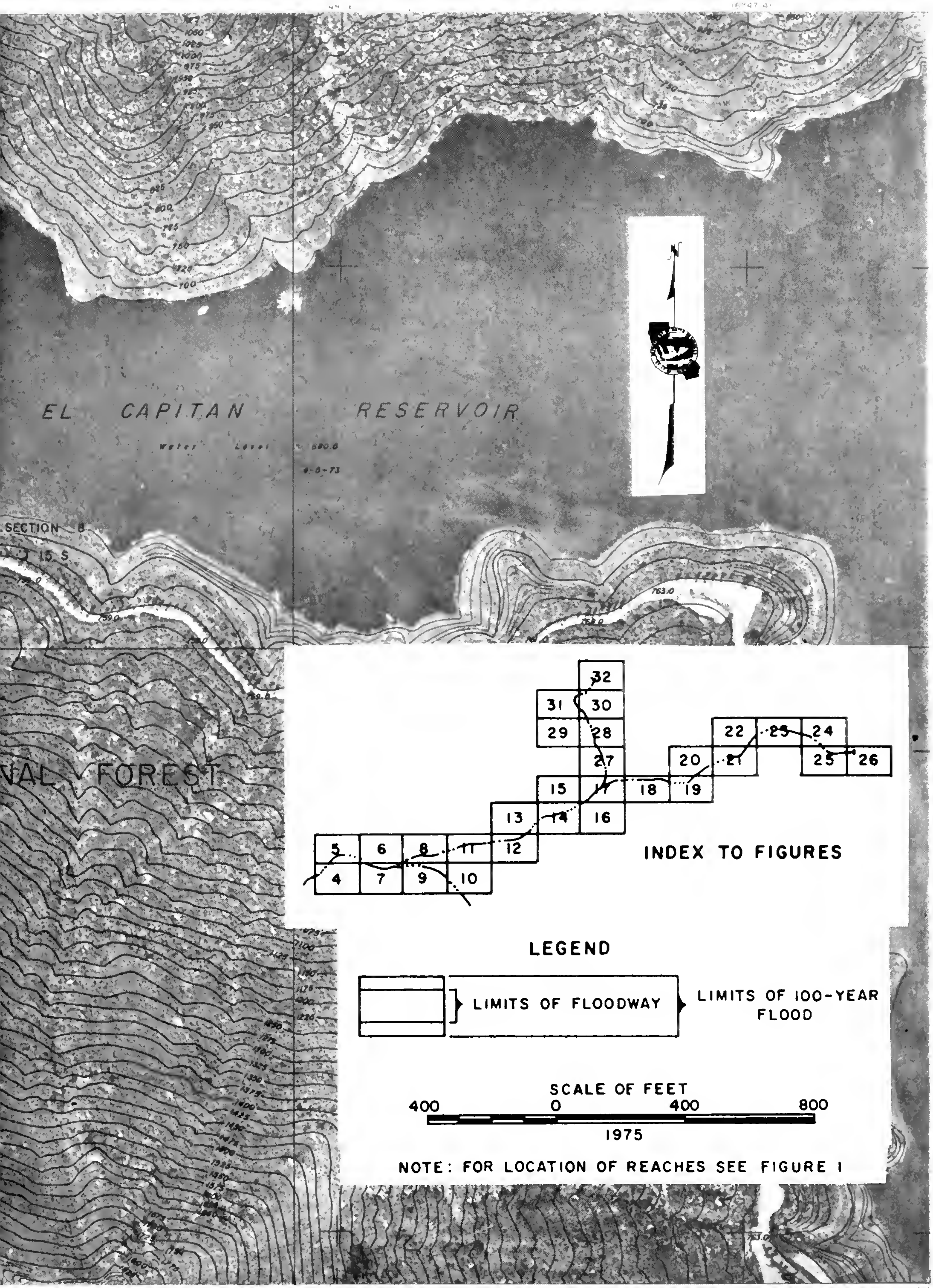


FIGURE 26-AREAS OF POTENTIAL INUNDATION FROM A 100-YEA



LOOD AND LOCATION OF FLOODWAY-REACH 9

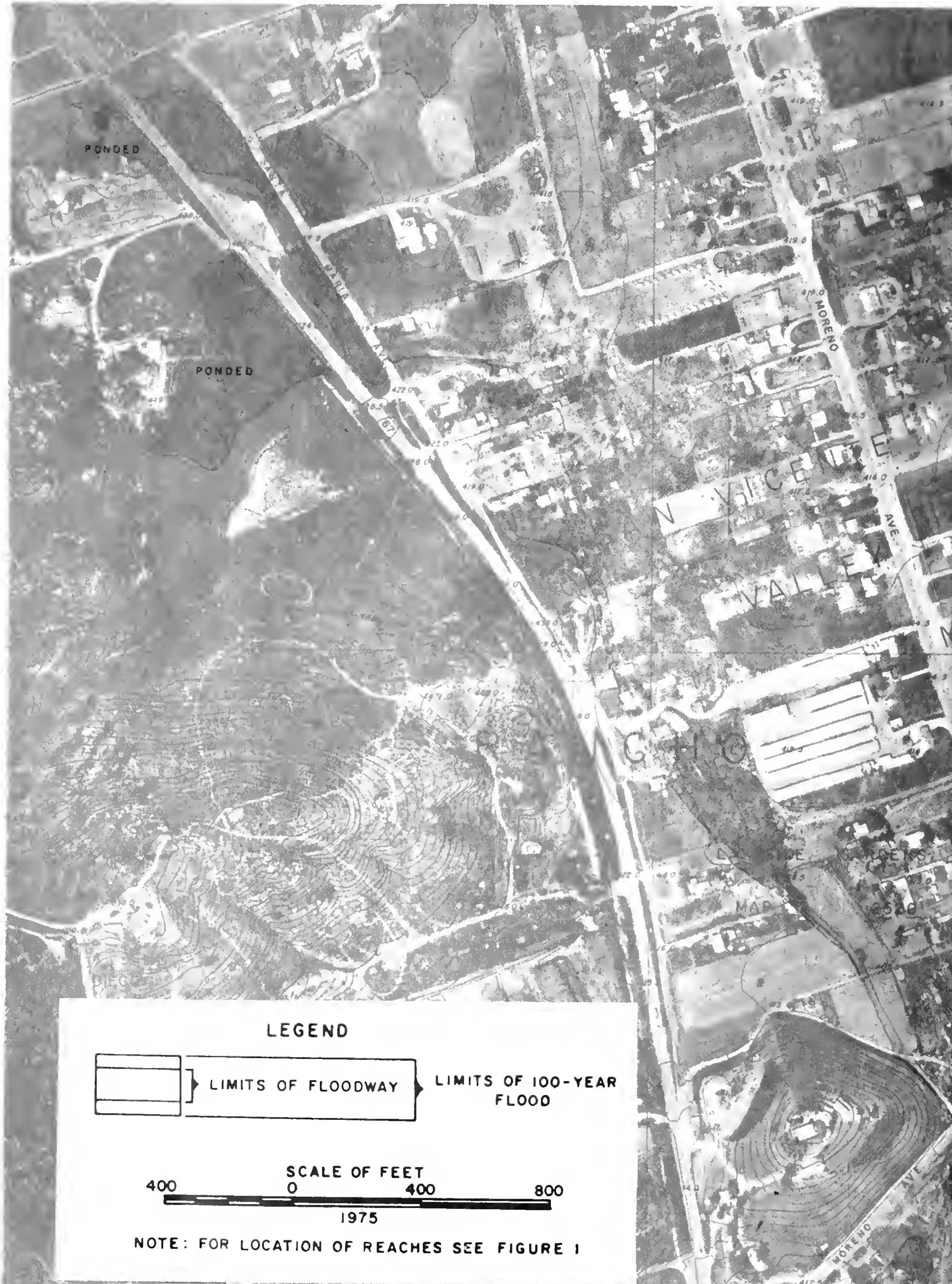
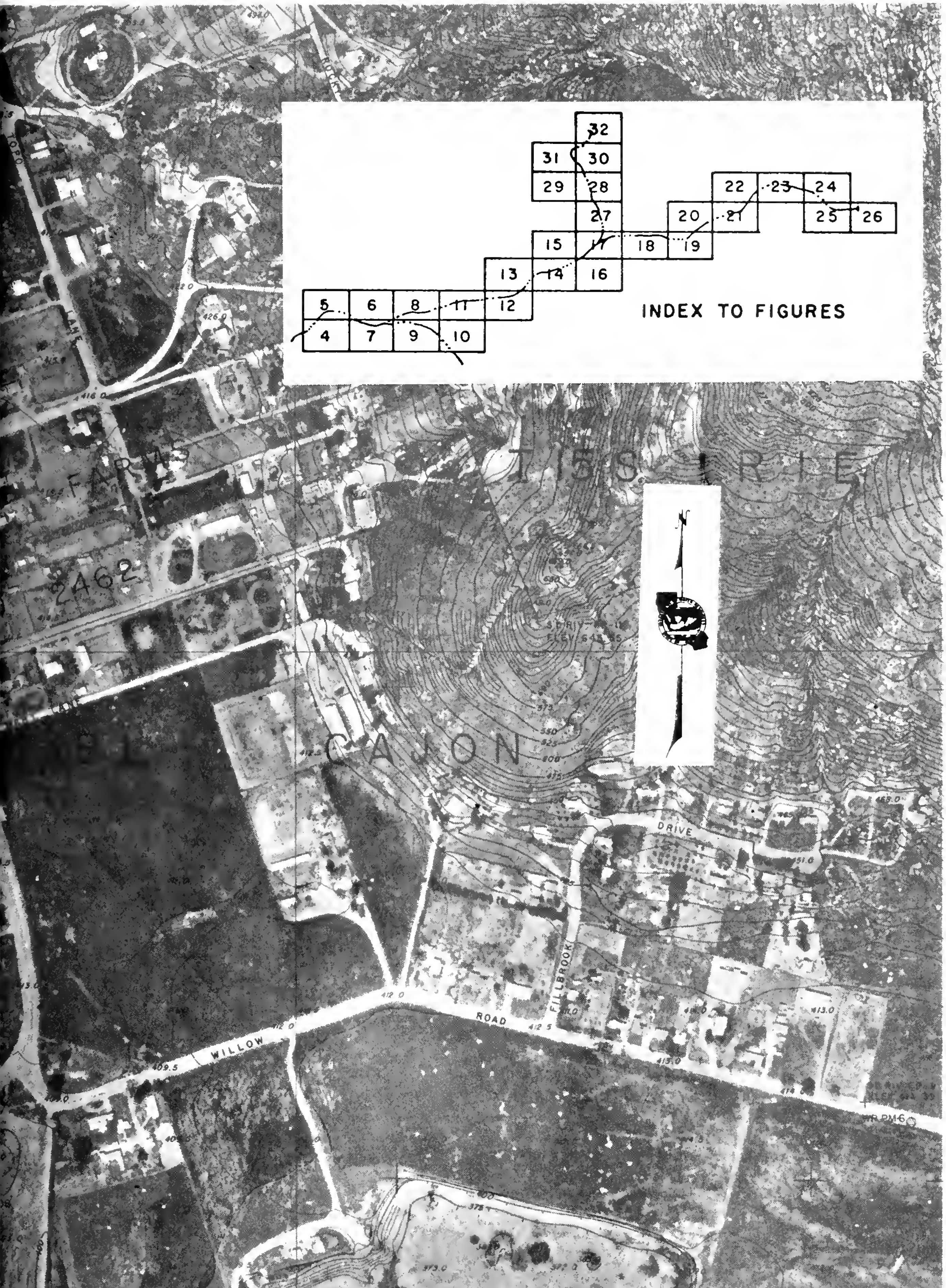


FIGURE 27-AREAS OF POTENTIAL INUNDATION FROM A 100-YEAR



LOOD AND LOCATION OF FLOODWAY - REACH 10

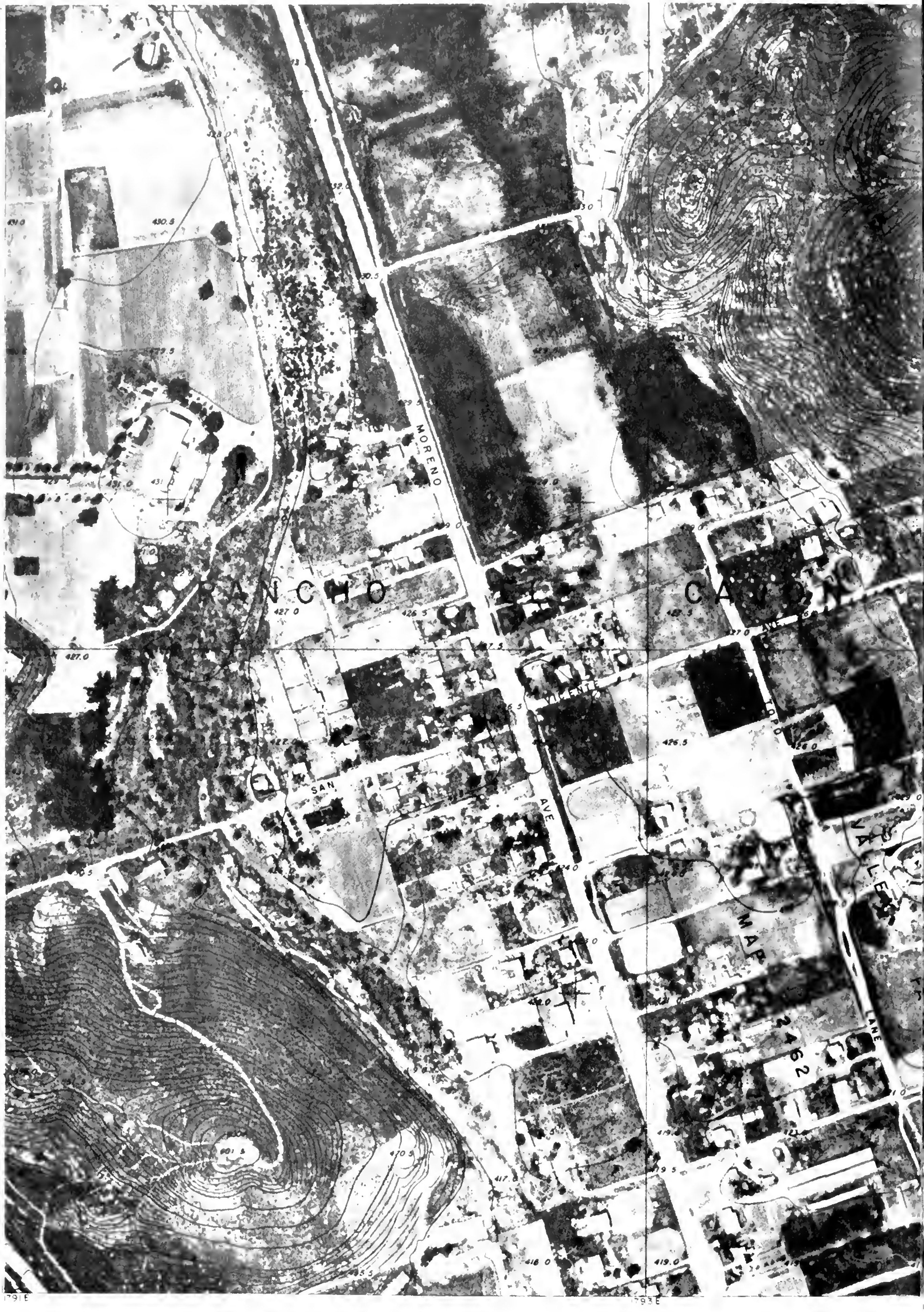
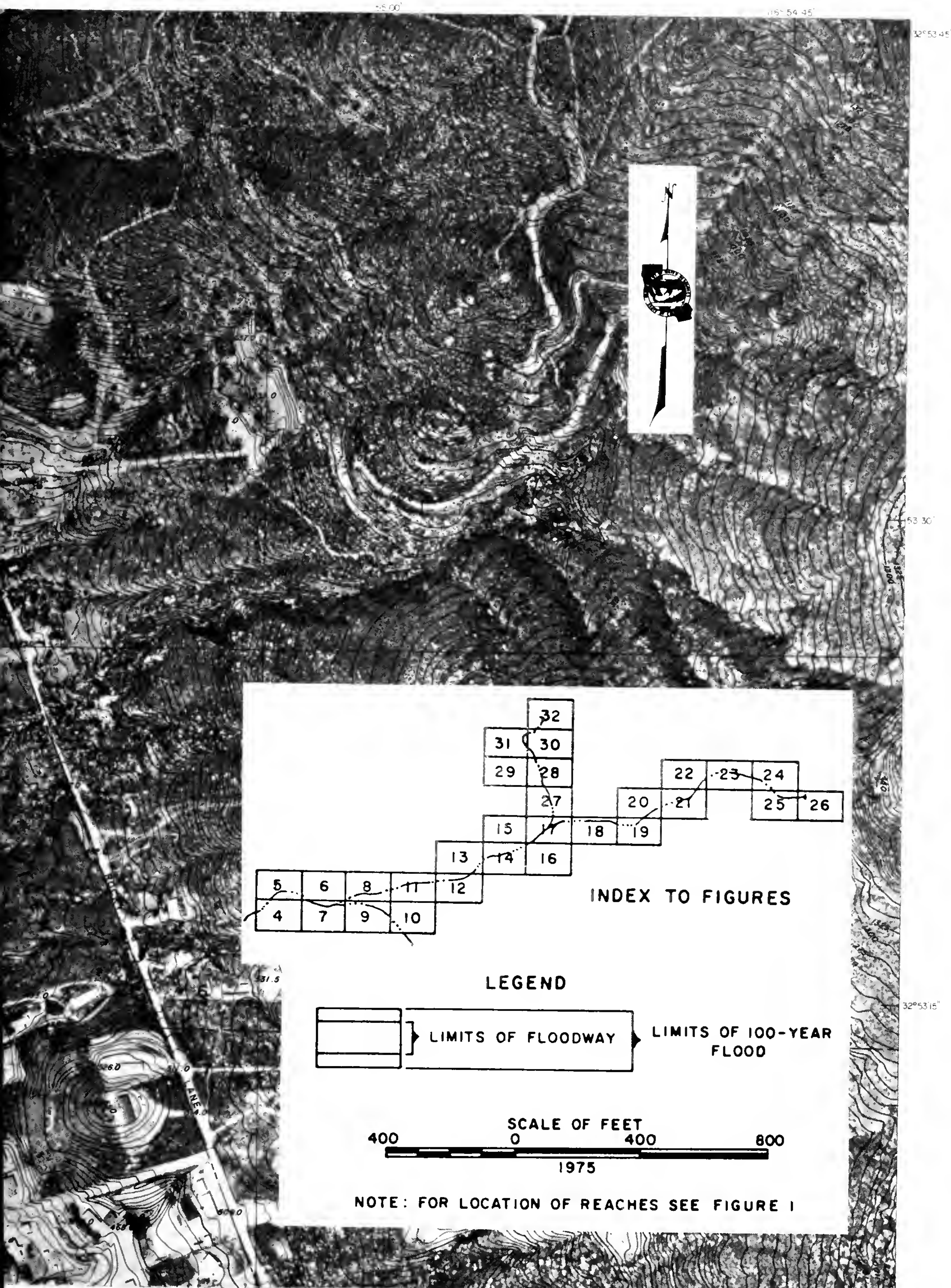


FIGURE 28 - AREAS OF POTENTIAL INUNDATION FROM A 100-YE



D AND LOCATION OF FLOODWAY-REACH 10

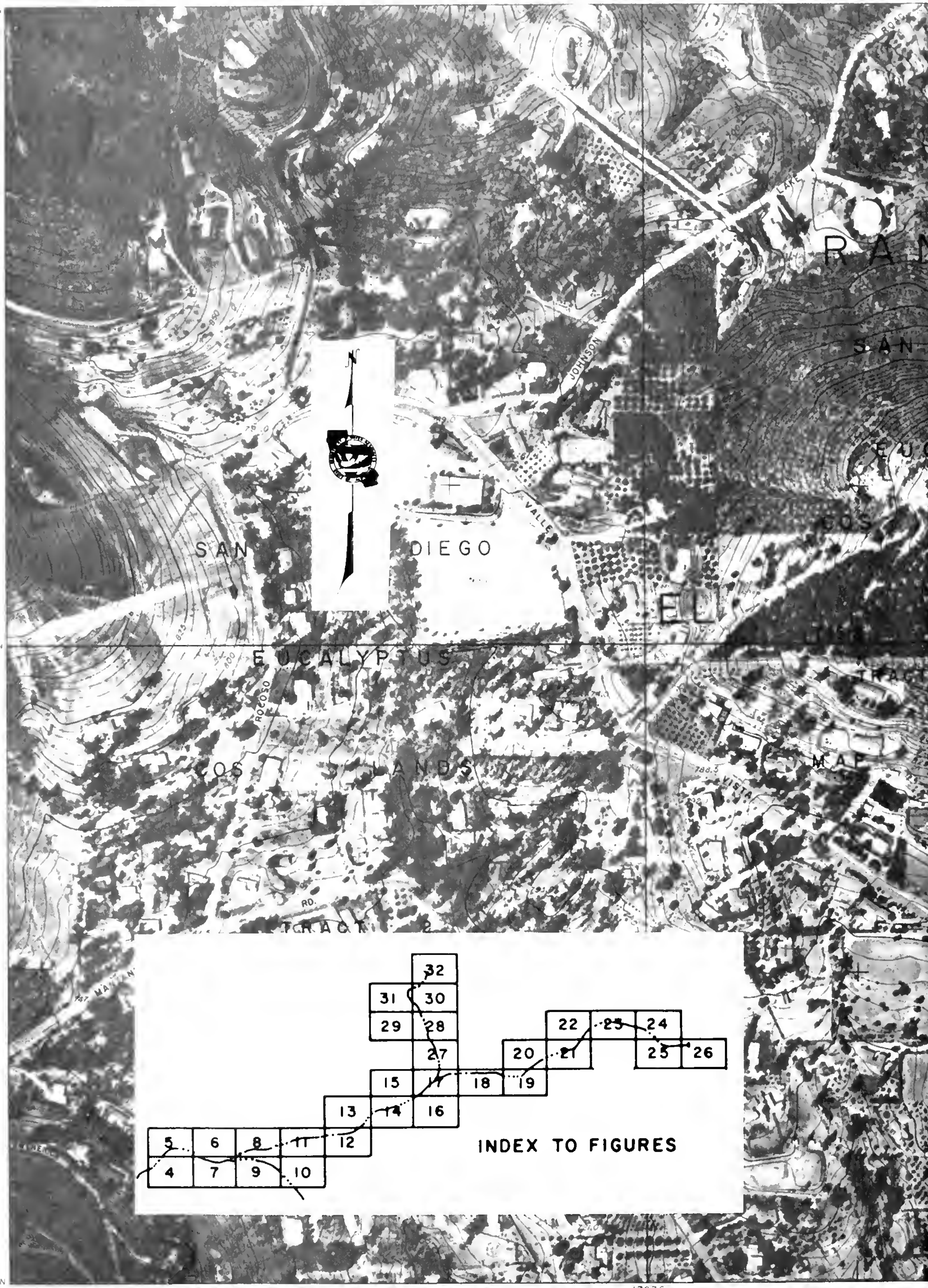
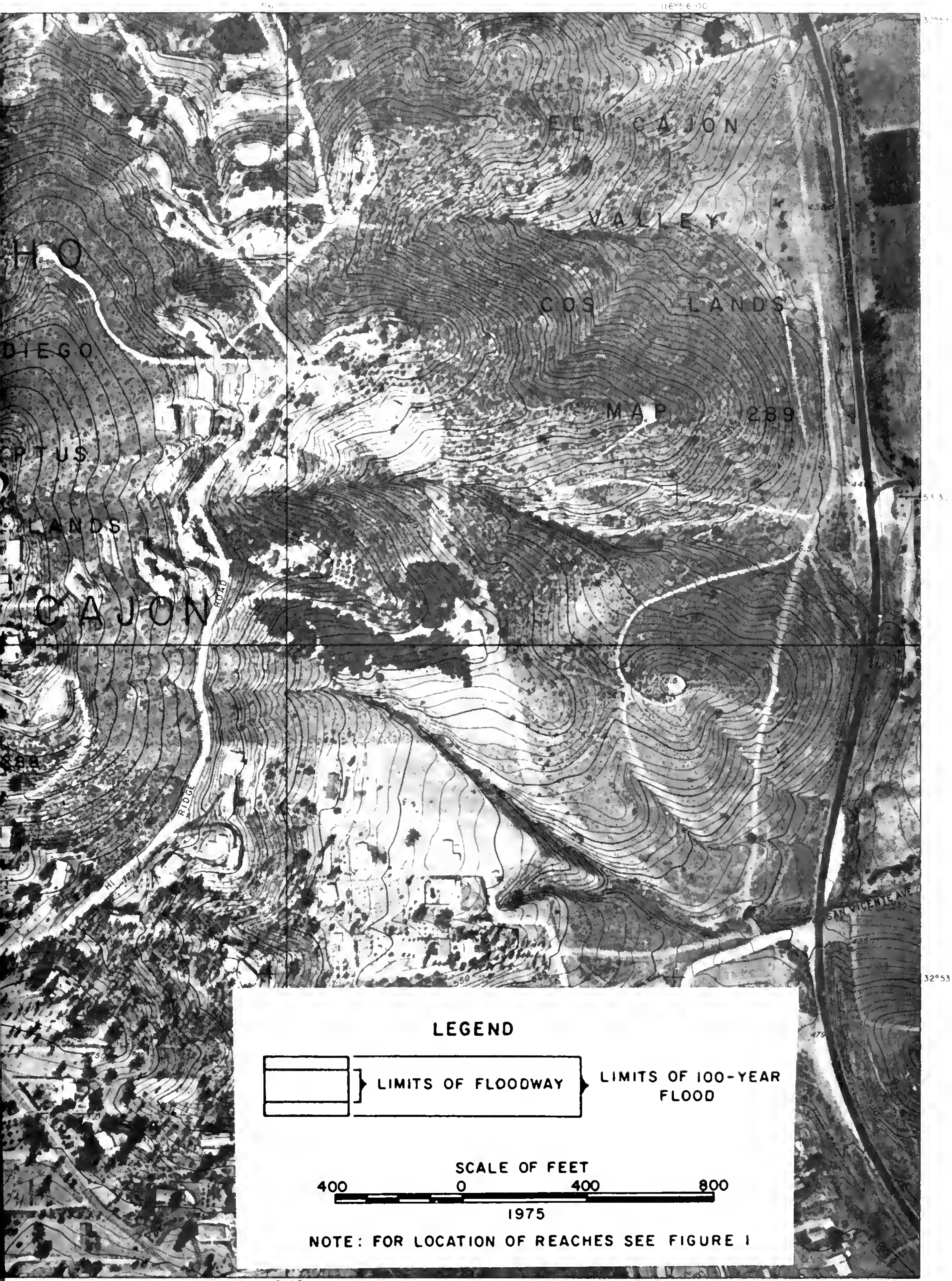


FIGURE 29-AREAS OF POTENTIAL INUNDATION FROM A 100-YEA



OOD AND LOCATION OF FLOODWAY - REACH 10

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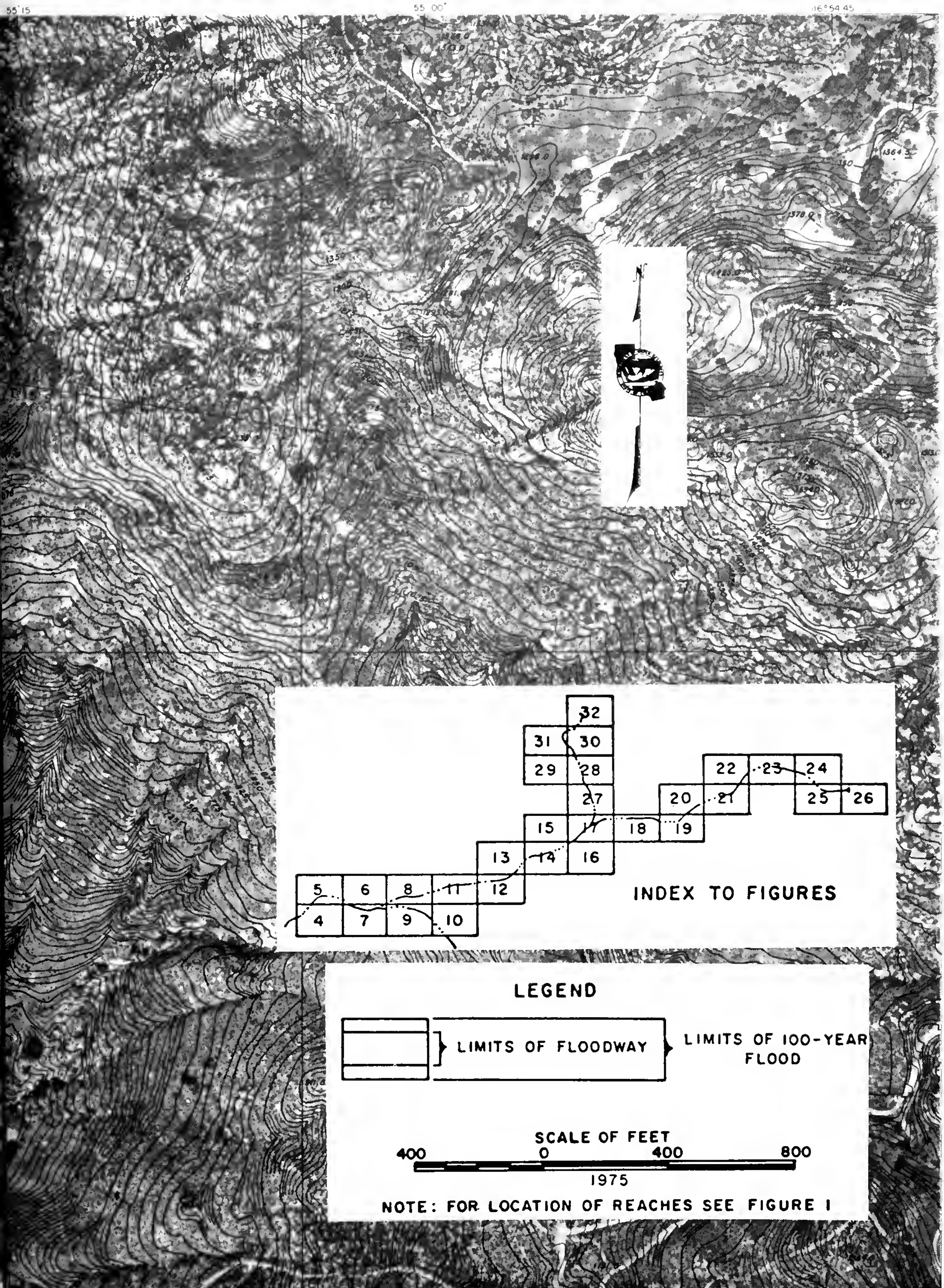
FIGURE 30-AREAS OF POTENTIAL INUNDATION FROM A 100-YEA



LOOD AND LOCATION OF FLOODWAY - REACHES 10, 11 AND 12

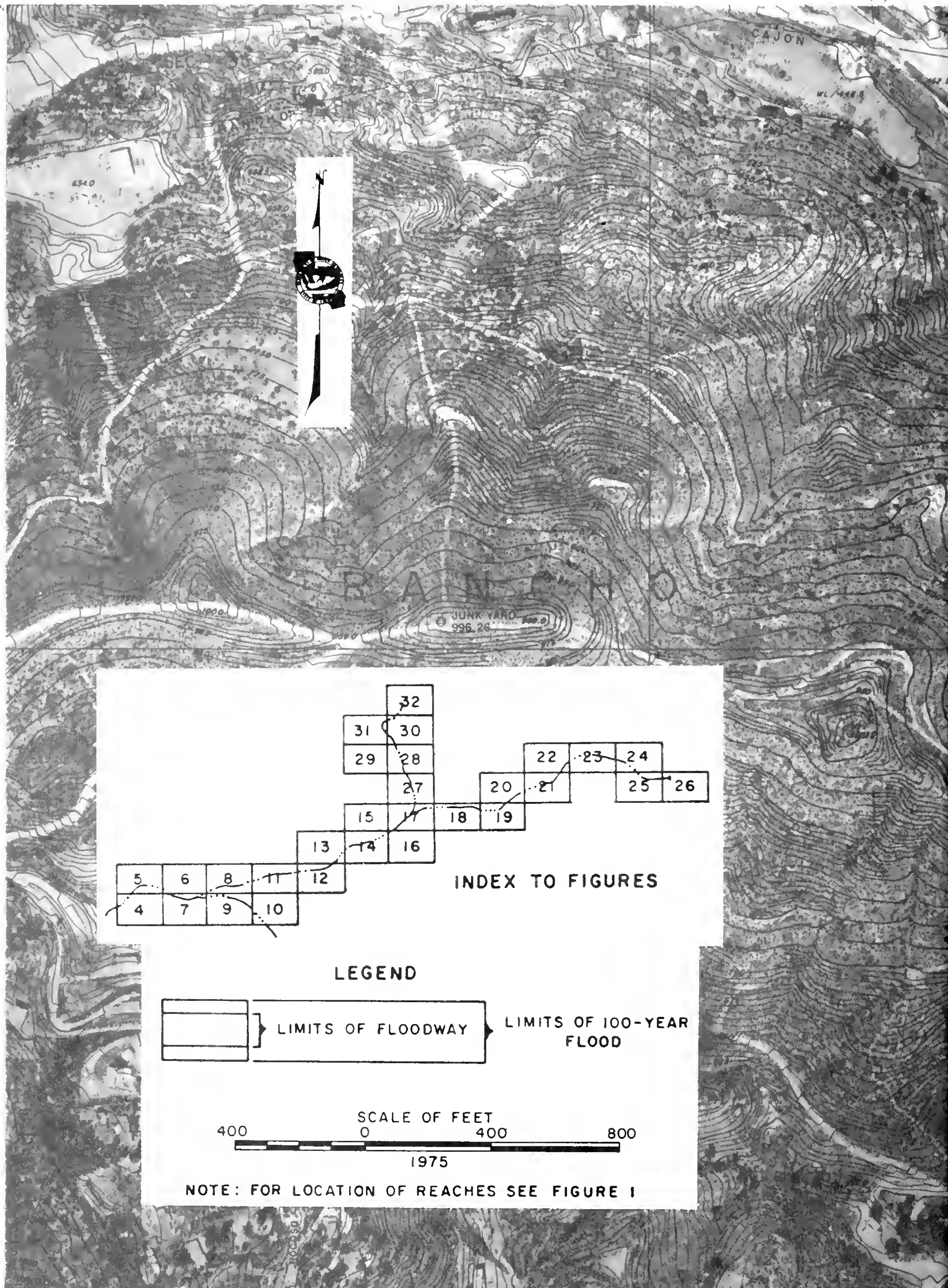
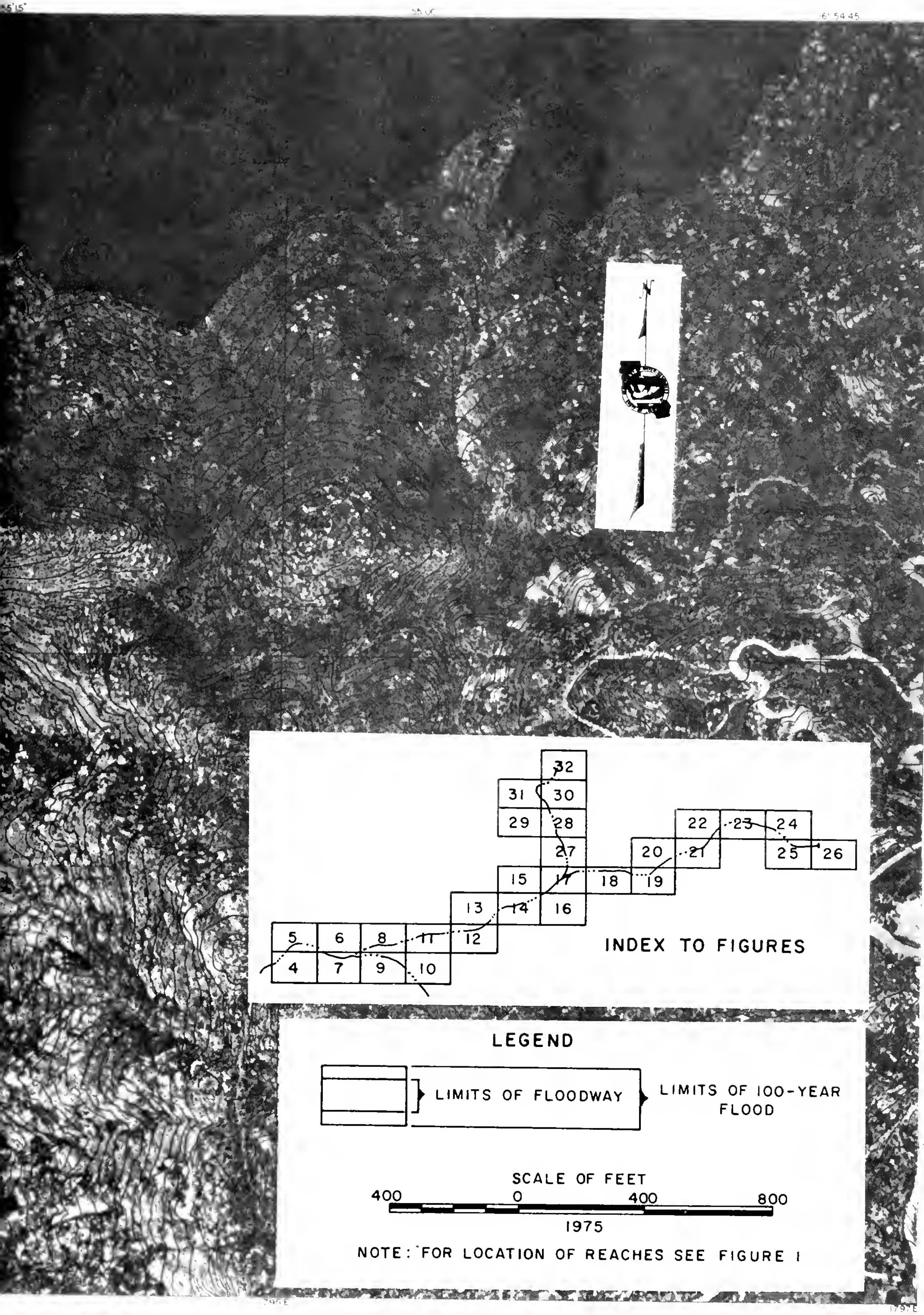


FIGURE 31-AREAS OF POTENTIAL INUNDATION FROM A 100-YEA

LOOD AND LOCATION OF FLOODWAY-REACHES 10 AND 11

FIGURE 32-AREAS OF POTENTIAL INUNDATION FROM A 100-YEA



OOD AND LOCATION OF FLOODWAY-REACH 12

CHAPTER 4. ALTERNATIVE FLOOD CONTROL MEASURES

This study examined and compared a number of structural and nonstructural flood control measures. These measures, as detailed below, were concrete-lined channels, grass-lined channels, earth channels, and floodplain zoning. Based on a reconnaissance-level study of these alternatives, none of the structural measures proved to be feasible. The nonstructural measure of floodplain zoning was found to be the best means of reducing future flood damages.

For purposes of this study, the Upper San Diego River was divided into nine reaches (Figure 1 and Table 4) extending from Mission Dam to El Capitan Dam. San Vicente Creek was divided into three reaches from its confluence with the San Diego River to San Vicente Dam.

TABLE 4

LOCATION OF REACHES FOR FLOOD CONTROL ALTERNATIVES

	Upper San Diego River
1	From Mission Dam to approximately 1,600 feet upstream
2	To west end of Carlton Oaks golf course
3	To Sycamore Canyon
4	To approximately 900 feet west of Magnolia Avenue
5	To Lakeside Water Pollution Control Facility
6	To Channel Road
7	To Highway 67 Lakeside bridge
8	To El Monte Park
9	To El Capitan Dam
	San Vicente Creek
10	From Lakeside bridge to Vigilante Road
11	To Moreno Drive
12	To San Vicente Dam

These reaches, which were selected in cooperation with the County, reflect the most appropriate or desirable location to change from one alternative flood control measure to another. All the alternative measures were designed on the basis of the peak 100-year-frequency flood discharges. No alternatives were studied for Forester Creek because San Diego County has already developed plans for a flood control channel for portions of the creek. It is anticipated that the reach from the creek's confluence with the San Diego River to Mission Gorge Road will be constructed by the State Department of Transportation in connection with the proposed Highway 52 freeway. The Department of Transportation has already acquired the rights of way, and plans call for construction of a flood control channel compatible with the County's Forester Creek improvement. Freeway construction is set for 1990. Construction of the sections upstream from Mission Gorge Road has been scheduled in two steps: (1) a temporary grass-lined trapezoidal channel having a design capacity of a 10-year-frequency flood and (2) a concrete-lined channel designed for a 100-year-frequency flood. The rights of way are being acquired for the trapezoidal channel.

No structural alternatives were studied for reaches 1, 9, and 12. Construction of flood control channels is not justified in these three reaches for three reasons: the floodplains are very narrow, channel construction requires a certain width of floodplain, and there is hardly any present or potential development to be protected.

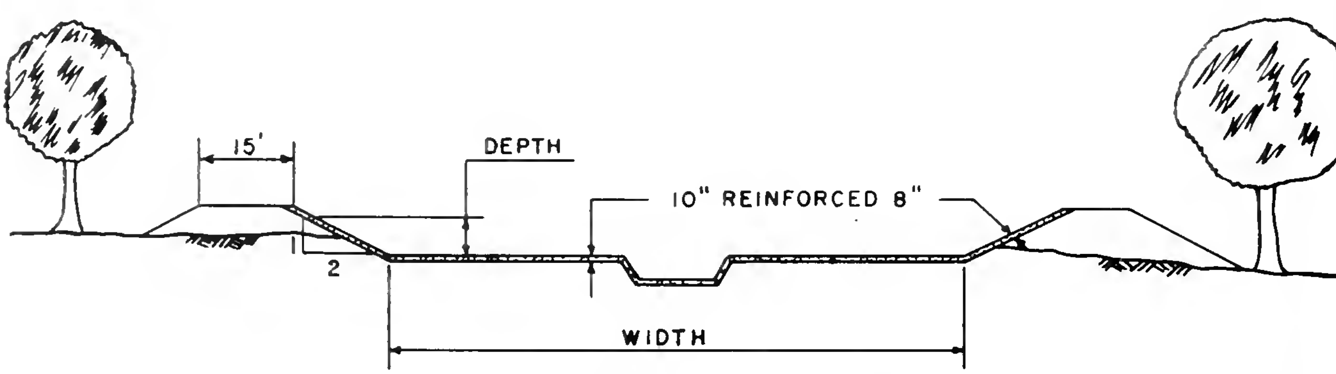
Structural Measures

Three types of structural measures were considered in this study: (1) a concrete-lined channel (Figure 33), (2) an earth channel with stone-protected sides (Figure 34), and (3) a grass-lined channel (Figure 35).

The concrete-lined channel would be trapezoidal in shape with side slopes of 2:1 and a base width ranging from 65 to 130 feet. Its invert slope would range from .0018 to .0045 that would carry flows at a velocity of 22 feet per second. A freeboard of 3 feet was used over the design flow depth.

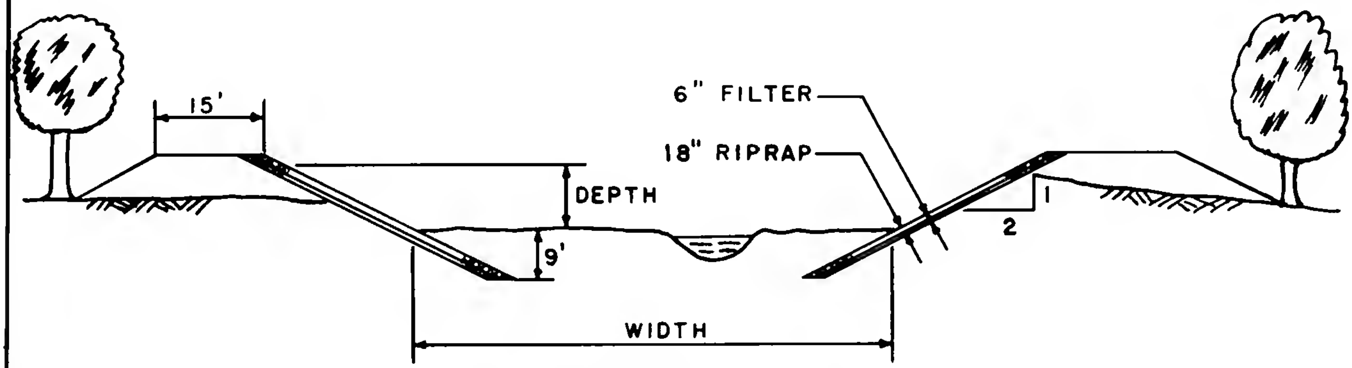
The earth bottom channel with stone-protected sides was designed for a flow with a velocity of 10 feet per second. Above that velocity it is customary practice to grout the stone-protected sides, which greatly increases the cost. A freeboard of 3 feet was used for the section.

The design of the grass-lined channel calls for a broad base ranging from 300 to 510 feet with gentle 4:1 side slopes that would blend with the natural environment. Bermuda grass has been chosen for this reach because it is hardy and, though it turns brown during the winter, can withstand quite high water velocities. The channel's velocity would be limited to about 8 feet per second; that appears to be the upper limit for Bermuda grass and is the velocity at peak discharge for a 100-year-frequency flood. For smaller discharges, velocities would be lower. The natural terrain dictates construction of four drop structures in conjunction with the grass-lined and earth channels to control downstream erosion. Drop structures control erosion by dissipating energy and reducing the velocity downstream. The drop structures would be located (1) near Cuyamaca Street (2) near the Lakeside Water Pollution Control Facility, (3) near Channel Road, and



	REACHES 2 to 7	REACH 8	REACHES 10 & 11
Discharge (cfs)	33,000 to 38,000	20,000	16,000
Width (feet)	90 to 130	90	65
Depth (feet)	10 to 13.7	7.8 to 8.5	8.7
Freeboard (feet)	3	3	3
Invert Slope	.0018 to .0025	.0033 to .0045	.0038
Velocity (ft./sec.)	22	22	22
Manning's "n"	.014	.014	.014

Figure 33 – TYPICAL CROSS SECTION OF A CONCRETE-LINED CHANNEL



	REACHES 2 to 7	REACH 8	REACH 10
Discharge (cfs)	33,000 to 38,000	20,000	16,000
Width (feet)	225 to 250	200 to 250	160
Depth (feet)	11 to 14	7.2 to 9	8.7
Freeboard (feet)	3	3	3
Invert Slope	.0018 to .0025	.0033 to .0045	.0038
Velocity (ft./sec.)	10	10	10
Manning's "n"	.030	.030	.030

Figure 34 – TYPICAL CROSS SECTION OF AN EARTH CHANNEL

(4) near Highway 67 (Lakeside bridge). Alternative measures such as building new dams or enlarging existing ones were considered but not evaluated.

Based on the City of San Diego's January 1973 report titled "San Diego River Mission Valley Flood Control Task Force Report", the cost of constructing new dams would be very high in relation to the benefits derived. Although the examination of such a possibility is beyond the scope of this study, it appears that future sand mining operations in the streambed could be carried out in such a way as to form a continuous channel. With this type of channel improvement, the floodplain could be greatly reduced with minimal cost.

Other multipurpose uses could be developed in conjunction with the flood control channel. These include conservation of flood waters, recreation, and fish and wildlife enhancement. All of these uses are discussed in detail in Chapter V.

One of the methods of conserving water is the replenishment of the ground water basin. This is done by trapping storm water or filling spreading basins with imported water and allowing the water to percolate into underground reservoirs. In the case of the earth channel, this could be accomplished by constructing dikes (or inflatable rubber dams) across the channel that would wash out (or be deflated) during high flows. In the case of the concrete-lined channel, spreading basins could be constructed adjacent to the channel.

For the grass-lined channels, spreading grounds could be created in portions where no fertilizers are used and where storm flows are led to the spreading grounds by low-flow channels. At present, the total dissolved solids (TDS) of the subsurface water in the reach from Mission Dam to Lakeside bridge is about 1,100 to 1,500 milligrams per liter (mg/l), and in the reach from Lakeside bridge to El Capitan Dam the TDS varies from 600 to 1,100 mg/l.

Recreational development within the channel right of way would be in general agreement with the open space greenbelt concept of the Santee and Lakeside community plans. Within the earth channel, recreational facilities such as hiking and equestrian trails could be provided. The grass-lined channel could be used for golfing, picnicking, and park activities. Although the construction of a concrete-lined channel is in conflict with the overall concept of the open space planning adopted by the communities, this plan could accomodate hiking and biking facilities. Instead of using conventional concrete drop structures, grouted rocks and boulders could be landscaped to create a waterfall effect for small flows, which would lead to downstream pools. These pools, low-flow channels, and intermittent ponds could be used for fishing, and with vegetative planting would create a natural habitat and sanctuary for birds and wildlife.

The grass-lined channel and earth channel could be combined to obtain advantages of both.

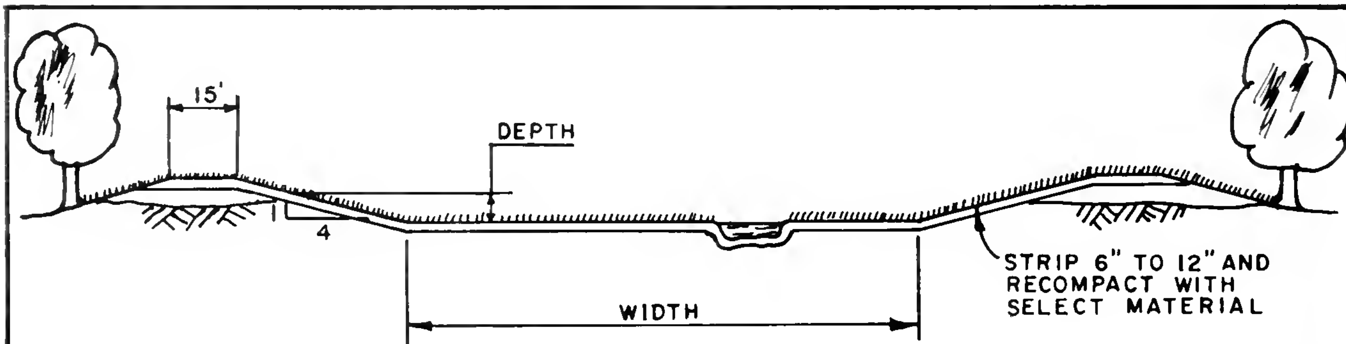
Nonstructural Measures

The traditional method to control floods and to mitigate flood damages has been to build dams, levees, and channels.

Currently, due to public concern about the environment, there is considerable opposition to these traditional structural measures, and growing interest has developed in nonstructural measures, such as floodplain management, flood warning systems, watershed management, and flood proofing.

Floodplain Management

Recognizing the importance of floodplain management in particular, the County of San Diego some time ago adopted regulatory zoning in many of its floodplains. Appendix A contains the



	REACHES 2 to 7	REACH 8	REACH 10
Discharge (cfs)	33,000 to 38,000	20,000	16,000
Width (feet)	300 to 440	360 to 510	350
Depth (feet)	10 to 12	4.7 to 6.2	5.5
Freeboard (feet)	3	3	3
Invert Slope	.0018	.0033 to .0045	.0038
Velocity (ft./sec.)	8	8	8
Manning's "n"	.035	.035	.035

Figure 35 – TYPICAL CROSS SECTION OF A GRASS-LINED CHANNEL

flood-related portions of the County Zoning Ordinance. For purposes of this study, floodplain zoning was considered "as is" alternative.

The County, by ordinance, has divided the floodplain into a "floodway" for carrying the flood waters and a "flood fringe" on which buildings and other improvement can be built. The limits of a floodway are established by determining the area required to pass either:

A. The 10-year flood with no structural improvements (A on Figure 36), or

B. The 100-year flood, without increasing the water surface elevation of the 100-year flood more than 1 foot at any point (B on Figure 36),

whichever area is greater. The flood fringe then becomes all land in the floodplain but outside the floodway that would be inundated under a 100-year flood.

To preserve as natural an environment as possible, the area designated as floodway will for all practical purposes be completely devoid of new developments. Developments within the flood fringe will be allowed according to the land use zoning requirements and provided any structure built is adequately floodproofed against damages from a 100-year flood. The different methods of floodproofing are discussed later.

Floodplain zoning preserves the environment, provides protection to life and property, and reduces the financial burden of public agencies and property owners by eliminating or lessening the need for constructing and maintaining flood control facilities which would be required if unplanned developments were permitted.

-Union Title Historical Photo Collection

Lakeside at Highway 67--1916 flood

The county ordinance fully meets and is compatible with requirements set by the U. S. Department of Housing and Urban Development for the federally subsidized National Flood Insurance Program. The National Flood Insurance Program was authorized by Congress in 1968 making available for the first time flood insurance to individuals at affordable rates. The program is federally subsidized and the local government in return for this subsidy is required to adopt certain minimum land use measures to reduce or avoid future damage within its flood-prone areas.

Flood-prone areas are defined by the Federal Insurance Administrator in the U. S. Department of Housing and Urban Development from studies conducted by consultants and/or other governmental agencies. Such a study was conducted by the U. S. Army Corps of Engineers for the County of San Diego, using data developed for this bulletin to define the flood-prone areas for the upper reaches of the San Diego River.

The program was somewhat changed in December 1973 with the passage of the Flood Disaster Protection Act by Congress. The Act expanded the available limits of flood insurance coverage and imposed two new requirements on property owners and communities. The two new requirements as of March 2, 1974, are (1) all property owners in communities

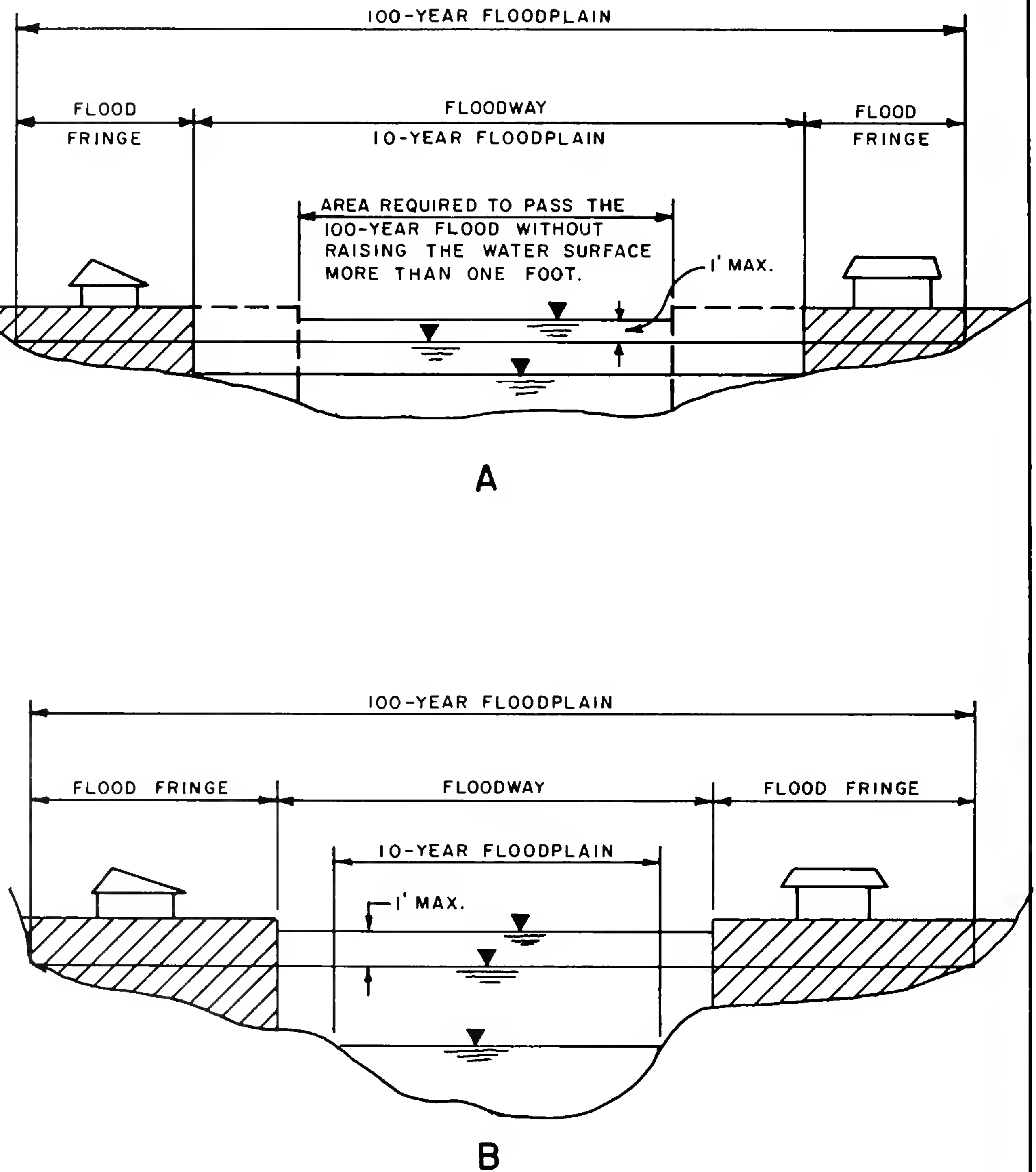


Figure 36 - DETERMINATION OF LIMITS OF FLOODWAY

DEPARTMENT OF WATER RESOURCES, SOUTHERN DISTRICT, 1975

where flood insurance is sold must purchase flood insurance to be eligible for any new or additional Federal or federally-related financial assistance for any buildings located in areas identified by Department of Housing and Urban Development as having special flood hazards, and (2) all identified flood-prone communities must enter the program by July 1, 1975, or within one year from the identification of flood-prone areas by the Federal Insurance Administrator, whichever is later. After this date, financial sanctions become effective.

Flood Warning Systems

Flood warning systems can be effective in preventing loss of life and in reducing flood damage. With advance flood warning, downstream areas can be evacuated and flood protective measures can be initiated. A flood warning system would include the installation of radio-operated precipitation and stream measuring stations, a computerized forecasting system, and an information center. The Department of Water Resources and the San Diego County Department of Sanitation and Flood Control have just completed a cooperative study, where the department has provided input data to the County for the development of a flood forecasting procedure by the County.

Watershed Management

Watershed management includes a broad spectrum of people's activities affecting land use. In the Upper San Diego River Basin, one of the most serious watershed management problems arises from uncontrolled fires. The fires remove thick underbrush and chaparral, stripping the moisture-retaining ground cover from the soil. Peak runoff from the barren slopes increases and soil erosion takes place. The growing public use of forested areas increases the incidence of fires as the majority of fires are caused by people. The incidence of uncontrolled fires can be reduced by controlling growth of brush, developing fuel breaks, use of controlled burning, and implementation of improved fire-suppression-prevention programs. Contour shaping of steep slopes and maintaining a program of planting on cuts and fill slopes tend to reduce flood peaks and forming of debris-laden flows.

Flood Proofing

Flood proofing involves protecting structures and/or contents from the damaging effects of floods. Buildings that are structurally adequate to resist the effects of floodwater but whose contents are subject to damages could be flood proofed by providing flood shields over the openings.

Constructing walls or levees around structures or raising the elevation of buildings either by earth fills or structural columns are other ways of flood proofing. Using compacted levees along the boundaries of the floodway would be a cheaper method of flood proofing if a large area in the flood fringe were to be developed at one time.

CHAPTER 5. COMPARISON OF ALTERNATIVES

The alternative flood control measures evaluated in this investigation are compared on the basis of costs, benefits, and environmental effects.

Costs

The capital costs for flood control channels include construction costs, property costs, costs for relocation of utilities, roads, and bridges, and allowances for engineering and interest during construction. The construction costs are based upon prevailing rates as of July 1974.

Annual costs include operation and maintenance costs and amortization over a 50-year period, using an interest rate of six percent.

The major costs for construction of the concrete-lined channel are for excavation, compacted fill, reinforced concrete lining and relocation of roads and utilities. As the concrete-lined channel is designed for high-velocity supercritical flow, all the road crossings would be bridges instead of dip sections. The costs of earth work and right of way for a concrete-lined channel are less than those for an earth or grass-lined channel, but this is more than offset by the high cost of reinforced concrete lining.

The major costs of an earth channel are for excavation, compacted fill, stone slope protection, drop structures, and relocation of roads and utilities. The cost of an earth channel is less than the cost of either a concrete-lined or grass-lined channel. This is mainly due to the fact that the bed of the earth channel, which constitutes the major portions, does not need any protective lining.

The items of costs included in the grass-lined channel are the same as those for the earth channel except, instead of stone slope protection, grass lining is used for the entire section.

Cost estimates of the alternative channels are presented in detail in Appendix B. No cost estimates were prepared for other multipurpose uses of the channel, such as water conservation, recreation, or fish and wildlife enhancement. No costs for mitigation were identified.

Benefits

The benefits that could be realized from flood control measures include (1) reduction in damage to property, crops, utilities, highways, and bridges; (2) enhancement of land values; and (3) savings of costs of flood proofing structures on the flood fringes in the form of either raising foundations on stilts or compacted fills (Figure 37).

The benefits for the structural flood control alternatives are based on conditions which would exist under the floodplain zoning regulations adopted by the County. The benefits from property damage reduction include damages to existing property only. This is because without a flood control channel, no new development would be allowed within the floodway, and any new development in the flood fringes would be allowed only if the first floor of the structure is 1 foot above the water surface elevation of the 100-year flood (Figure 37). The cost involved in raising the floor of structures would be considered a benefit as this would not be necessary with a flood control channel. Another benefit of a flood control channel would be enhancement of land values. No enhancement of land values is considered

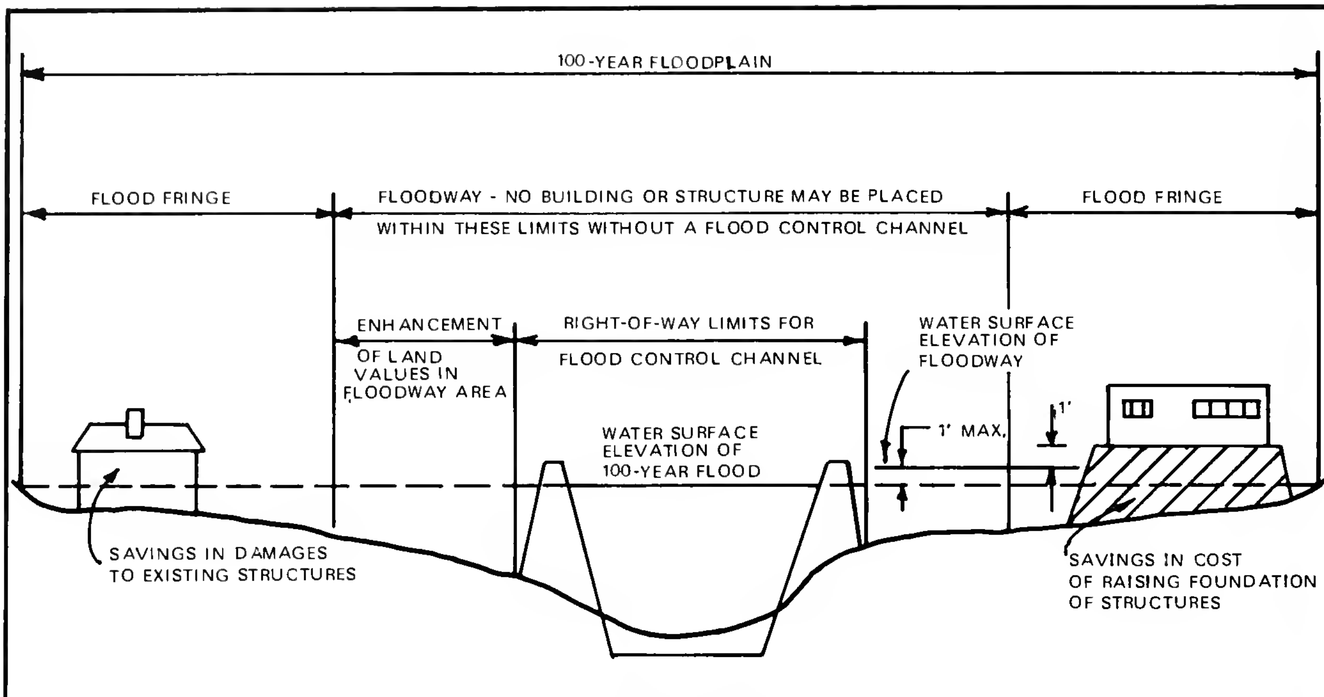


Figure 37. TYPICAL CROSS SECTION SHOWING BENEFITS FROM STRUCTURAL FLOOD CONTROL MEASURES

in the flood fringes as it is assumed that development would continue at the same pace with or without a flood control channel. However, within the floodway and outside the rights of way limit of the flood control channel, the land values would be enhanced based on location and type of channel. Areas inundated for a 100-year flood and those required for the three different types of channels are presented in Table 5.

Damages Prevented

In the study area, the lower portion of San Vicente Creek is the only area where benefits due to damage reduction would be significant. A number of buildings are located in the floodplain. Damages for different frequency floods were calculated, using the depth-damage curves prepared by the Corps of Engineers for similar studies. For purposes of this report, an escalation of 1.5 percent per year was used to calculate the probable future damages. The average annual damages for lower San Vicente Creek were calculated to be $19,00 to structures and contents and approximately $3,000 to utilities, roads, and agriculture, plus indirect damages.

Enhancement

According to the San Diego County Planning Department and the communities of Santee and Lakeside, there would be comparatively little development of land even with flood protection, except for reaches from Carlton Hills Boulevard to the Lakeside Water Pollution Control Facility (reaches 4 and 5) located in Santee. The preliminary Santee Community Plan indicates that the land adjacent to the floodplain in reaches 4 and 5 could be developed to the extent of from 5 to 25 dwelling units per acre. Value of the land adjacent to the floodplain within the floodway but outside the flood control channel would be enhanced considerably in reaches 4 and 5. It is assumed that the land outside the grass-lined channel in these reaches would increase in value by

approximately $10,000 per acre and that the earth channel would increase values by approximately $7,000 per acre. The present market value is about $2,000 to $3,000 per acre.

Flood Proofing

Flood proofing consists of raising building foundations above the level of 100-year-frequency flood fringe areas. In most of this reach it would range from 1 to 4 feet and the cost would range from $1,000 to $3,000 per dwelling unit. For reaches 4 and 5 it is assumed that on the average there would be seven dwelling units per acre and that full development would take place in a span of 20 years. In other reaches development would be insignificant.

Recreation

Benefits and costs were not quantified for recreation features of the alternatives because the net recreation benefits are expected to be small, not nearly enough to offset the margin of other costs over other benefits for the various channels.

Reaches 4 and 5, which are located in Santee starting from Sycamore Canyon to the Lakeside Water Pollution Control Facility, present the best opportunity for developing recreational benefits. Recreation could be in the form of picnic area with ponds for fishing, and golf courses and riding stables which could be maintained by the County or leased out to private enterprise. The lease approach would not only produce revenues but also reduce capital and

TABLE 5
LENGTHS, AREAS OF INUNDATION AND AREAS REQUIRED FOR GRASS, EARTH AND CONCRETE CHANNELS FOR DIFFERENT REACHES

ITEMS	Upper San Diego River							San Vicente Creek	
	Reach 2	*Reach 3*	*Reach 4*	*Reach 5*	*Reach 6*	*Reach 7*	*Reach 8*	*Reach 10*	*Reach 11*
Length of Channel (Feet)	4,200	7,200	10,100	6,550	9,000	1,800	26,225	11,850	2,250
Area Inundated (Acres)									
100-Year Flood	141	207	444	243	359	101	704	490	74
Flood Way	106	173	210	87	211	40	414	270	55
Flood Fringe	35	34	234	156	148	61	290	220	19
Right of Way Required (Acres)									
Concrete-Lined Channel	28	48	59	38	50	10	130	72	11
Earth Channel	40	*	89	58	92	18	207	98	*
Grass-Lined Channel	51	*	121	75	125	25	333	154	*

Flood control channels were not studied for Reaches 1, 9 and 12 because of the very narrow floodplains in these reaches.
Length of each: Reach 1 - 1,600 feet; Reach 9 - 11,600 feet; and Reach 12 - 1,900 feet.

* See Table 6.

operation and maintenance costs. The communities of Santee and Lakeside, which comprise most of the floodplain, have designated their floodplain areas as open space greenbelt.

Water Conservation

Conservation of storm water by the use of dikes and rubber dams and creation of spreading ground could bring additional benefits.

Environmental Considerations

From an environmental point of view the different types of channels affect the natural vegetation, fish and wildlife, conservation of water, water quality, and recreation. The concrete-lined channel has the most adverse environmental effects and is the least desirable of the three alternatives. The earth and grass-lined channels are more compatible with the environment.

The effect of these alternatives on the amount of sand transported to the ocean cannot be evaluated without a more detailed study. However, it is anticipated that the concrete-lined and the grass-lined channels would reduce the amount of material transported downstream of the study area. This is due to the fact that in the California coastal

Table
ENVIRONMENTAL

Alternative	*Vegetation*	*Fish and Wildlive*
Channel left as is (Floodplain zoning)	No effect on floodplain vegetation which comprises about 70% of the length of the channel and includes riparian vegetation (willow, cottonwood, and sycamore), native shrubs, annuals, and grasses; (mustard, tree tobacco); agriculture; and golf courses. The other 30% consists of active and inactive gravel pits and ponds. Riparian vegetation is highly productive wildlife habitat and most threatened by floodplain development.	No effect on the many ponds containing warm water fish (bass, bullhead and channel catfish, blue gill, crappie, shad, et al) and providing habitat for a large variety of wildlife.
Concrete lined channel	Would eliminate all vegetation directly in the path of the channel, with no possibility of reestablishment. This type of channel would deny ground water for riparian vegetation adjacent to channel.	Would eliminate some of the ponds containing warm water fish. Habitat for small mammals, reptiles, and birds would be eliminated, and the channel could act as a barrier to wildlife crossing.
Earth lined channel	Would eliminate all vegetation directly in the path of the channel, but there could be regrowth of vegetation after construction.	Would eliminate some of the ponds containing warm water fish. Habitat for wildlife would be eliminated initially, but regrowth in channel bottom would provide some habitat, except at drop structure locations.
Grass lined channel	Would eliminate all vegetation in the path of channel, but would be replaced with grass.	Would eliminate some of the ponds containing warm water fish. Habitat for wildlife would be eliminated; however, planted grass or other vegetation could provide food source for some animals. Introduction of more diversified vegetation would increase value for wildlife.

region most of this material is derived from streambank and streambed erosion. Table 6 presents the environmental effects of the alternatives.

Economic Justification

Viewing the Upper San Diego River flood control improvement as a single project, it would not be justified economically to build any type of channel under existing and anticipated development. However, in reach 4, for the earth and grass-lined channels, a slight increase in benefits from change in land use could make these alternatives economically justified.

A comparison of costs and benefits for the alternative channels is presented in Table 7. However, it should be noted that values in Table 7 should be refined in the event one may suspect that a project may be justified because of change in value of enhancement of land. Table 7 does not reflect the reduction in benefits because of induced damages caused by floods greater than the design flood to the additional improvements created by the construction of the project.

These refinements were not made in this study as it would further reduce the benefits which were already less than the costs.

6
EFFECTS SUMMARY

Conservation of Water and Water Quality	*Recreation*	*Flood Protection*
Present channel allows percolation of runoff, but provides little erosion control. No effect on water quality. TDS is presently 1100 to 1500 ppm from Highway 67 Lakeside bridge downstream to Mission Gorge; and 1100 to 600 ppm upstream to El Capitan dam. Waste discharge of 4 mgd presently released into river from Santee Treatment Plant (upstream of Santee Lake).	No effect on area which is suitable for hiking, horseback riding and some fishing.	No protection to existing structures. Structures built in flood fringes would have to be flood proofed.
Would preclude percolation of runoff in the channel itself but erosion control would be complete. Water quality would be essentially unchanged from beginning of channel to end.	Bicycle riding and hiking would be possible.	All these plans would provide
Would allow some percolation of runoff and provide some erosion control. Water quality mineralization could increase due to stream contact with soil particles.	Hiking and horseback riding would be possible. Ponds could be constructed to provide fishing. Would be more aesthetically pleasing than concrete lined channel.	protection from a 1 in 100-year
Would allow some percolation of runoff and the grass would provide some erosion control. The grass would require irrigation, and possible application of fertilizers, herbicides, and insecticides which could deteriorate water quality.	Golfing, hiking, picnicking, horseback riding would be possible along with other park activities. Ponds could be reconstructed to provide fishing. Would be more aesthetically pleasing than concrete lined or earth lined channels.	flood.

TABLE
COSTS AND BENEFITS OF

Structural Measures	*Upper San Diego River*			
	Reach 2	*Reach 3*	*Reach 4*	*Reach 5*
CONCRETE-LINED CHANNEL				
Total Project Costs	$1,959,000	$3,611,000	$4,305,000	$2,945,000
Annual Costs				
Amortized Cost	124,000	229,000	273,000	187,000
O & M Costs	2,000	4,000	5,000	3,000
Total Annual Costs	126,000	233,000	278,000	190,000
Annual Benefits				
Flood Damages Prevented	1,000	3,000	2,000	1,000
Savings in Flood Proofing	1,000	1,000	75,000	51,000
Land Enhancement	8,000	-	29,000	9,000
Total Annual Benefits	10,000	4,000	106,000	61,000
EARTH CHANNEL				
Total Project Costs	$805,000	Earth and grass-lined channels were not considered in this reach as this reach consists of an 18-hole golf course, and the right of way required for an earth channel or a grass-lined channel would require purchase of the golf course estimated to cost over 1 million dollars.	$2,305,000	$1,755,000
Annual Costs				
Amortized Cost	51,000		146,000	111,000
O & M Costs	5,000		11,000	7,000
Total Annual Costs	56,000		157,000	118,000
Annual Benefits				
Flood Damages Prevented	1,000		2,000	1,000
Savings in Flood Proofing	1,000		75,000	51,000
Land Enhancement	13,000		54,000	13,000
Total Annual Benefits	15,000		131,000	65,000
GRASS-LINED CHANNEL				
Total Project Costs	$879,000		$2,350,000	$1,911,000
Annual Costs				
Amortized Cost	56,000		149,000	121,000
O & M Costs	8,000		19,000	12,000
Total Annual Costs	64,000		168,000	133,000
Annual Benefits				
Flood Damages Prevented	1,000		2,000	1,000
Savings in Flood Proofing	1,000		75,000	51,000
Land Enhancement	10,000		57,000	8,000
Total Annual Benefits	12,000		134,000	60,000

Note: Reaches 1, 9 and 12 were not studied because of the very narrow floodplains in the reaches.

7
ALTERNATIVE STRUCTURAL MEASURES

			San Vicente Creek		Total
Reach 6	*Reach 7*	*Reach 8*	*Reach 10*	*Reach 11*	
$4,021,000	$1,314,000	$9,393,000	$3,972,000	$524,000	$32,044,000
255,000	83,000	596,000	252,000	33,000	2,032,000
4,000	1,000	13,000	6,000	2,000	40,000
259,000	84,000	609,000	258,000	35,000	2,072,000
3,000	1,000	4,000	16,000	1,000	32,000
22,000	8,000	13,000	12,000	2,000	185,000
18,000	3,000	9,000	10,000	1,000	87,000
43,000	12,000	26,000	38,000	4,000	304,000
$2,551,000	$857,000	$4,354,000	$2,229,000	In this reach the relatively narrow width of the 100-year floodplain and the lack of development both for the present and future plans make the construction of an earth or a graas-lined channel economically infeasible.	$14,856,000
162,000	54,000	276,000	141,000		941,000
10,000	2,000	29,000	13,000		77,000
172,000	56,000	305,000	154,000		1,018,000
3,000	1,000	4,000	16,000		28,000
22,000	8,000	13,000	12,000		182,000
26,000	4,000	9,000	13,000		132,000
51,000	13,000	26,000	41,000		342,000
$3,414,000	$1,029,000	$5,547,000	$2,945,000		$18,075,000
217,000	65,000	352,000	187,000		1,147,000
17,000	3,000	50,000	23,000		132,000
234,000	68,000	402,000	210,000		1,279,000
3,000	1,000	4,000	16,000		28,000
22,000	8,000	13,000	12,000		182,000
33,000	5,000	5,000	11,000		129,000
58,000	14,000	22,000	39,000		339,000

CHAPTER 6. SUMMARY OF FINDINGS AND RECOMMENDATIONS

Findings

1. The Upper San Diego River area historically has been subjected to serious flooding problems; however, there have been no major floods since 1941.

2. El Capitan and San Vicente Reservoirs, constructed in 1935 and 1943, respectively, have provided incidental flood control benefits. The frequency and magnitude of the floods have been reduced considerably by the available storage space in El Capitan Reservoir.

3. Although the potential area of inundation along the Upper San Diego River is large, the damages to existing structures would be relatively small. This is due to the sparse development in the floodplains in most of the reaches.

4. The low level of development in the floodplain is a result of an active program of San Diego County to reduce flood hazards by limiting development in flood prone areas defined by earlier studies. The County's floodplain management practices have been proven to be an effective means of flood damage prevention.

5. Notwithstanding the efforts by the County, flood hazards still exist in the study area, particularly in the lower portion of San Vicente Creek where the damages to existing developments could be significant.

6. Both structural and nonstructural measures were considered for flood damage prevention. Of the several flood control structural alternatives studied, including concrete, earth, and grass-lined channels, none was found to be economically justified. The concrete-lined channel alternatives not only cost the most, but are also the least desirable from an environmental point of view. Although the earth channel seems to have a more favorable relationship of benefit to cost, the grass-lined channel may prove to be economically more desirable if the demand for recreation in the area leads to the development of parks and other recreation facilities. In the area from Carlton Hills Boulevard to the Lakeside Water Pollution Control Facility (reaches 4 and 5), the addition of recreational developments may, in the future, provide benefits high enough to justify either a grass-lined or an earth channel.

7. Nonstructural measures in the form of floodplain and watershed management, flood warning systems, and flood proofing, would provide the best overall means of reducing flood damage in the Upper San Diego River area.

Recommendations

1. The County should continue its floodplain management practices, including enforcement of existing floodplain zoning ordinances, and adoption of similar ordinances for Forester Creek and other uncontrolled floodplains.

2. The boundary of the various flood overlay zones for Upper San Diego River and San Vicente Creek, as defined in the County ordinances, should reflect the findings of this study.

APPENDIXES

Appendix A

COUNTY ZONING ORDINANCES

ARTICLE II

Section 61.1. "FLOOD PLAIN FRINGE" shall mean all that land in an FP Flood Plain Overlay Zone (FP Zone) or FC Flood Channel Overlay Zone (FC Zone) that is not within a floodway as delineated on the San Diego County Flood Plain Maps adopted by Resolution of the Board of Supervisors and filed with the Clerk of the Board of Supervisors, or in the event a floodway has not been so delineated, as determined by the Director, Department of Sanitation and Flood Control.

(Amended by Ord. 4375 (NS) adopted 8-28-74)

Section 61.2. "FLOODWAY" shall mean all that land in an FP Flood Plain Overlay Zone (FP Zone) or FC Flood Channel Overlay Zone (FC Zone) that is within a floodway as delineated on the San Diego County Flood Plain Maps adopted by Resolution of the Board of Supervisors and filed with the Clerk of the Board of Supervisors, or in the event a floodway is not shown on such maps, all such land determined by the Director, Department of Sanitation and Flood Control, to be within a floodway. The Board of Supervisors in establishing the boundaries of a floodway to be delineated on the San Diego County Flood Plain Maps and the Director, Department of Sanitation and Flood Control, in determining the boundaries of a floodway shall include within the floodway (1) all land required to pass the 10-year flood without structural improvements and (2) all land required to convey the 100-year flood without increasing the water surface elevation of the 100-year flood more than 1 foot at any point.

(Added by Ord. 3583 (NS) adopted 9-16-70) (Amended by Ord. 4031 (NS) adopted 1-16-73) (Amended by Ord. 4375 (NS) adopted 8-28-74)

Section 61.3 FLOOD, 100-YEAR. " 100-YEAR FLOOD" shall mean a flood estimated to occur on an average of once in 100 years (one percent frequency of occurrence) which is determined from an analysis of historical flood and rainfall records and computed in accordance with San Diego County Standard approved by the Board of Supervisors on May 19, 1970, and filed with the Clerk of the Board of Supervisors as Document No. 425449.

(Added by Ord. 3583 (NS) adopted 9-16-70)

Section 61.4 FLOOD, 10-YEAR. "10-YEAR FLOOD" shall mean a flood estimated to occur on an average of once in 10 years (ten percent frequency of occurrence) which is determined from an analysis of historical flood and rainfall records and computed in accordance with San Diego County Standard approved by the Board of Supervisors on May 19, 1970, and filed with the Clerk of the Board of Supervisors as Document No. 425449.

(Added by Ord. 3583 (NS) adopted 9-16-70)

ARTICLE XXVII-C
(Amended by Ord. 3846 (NS) adopted 2-23-72.)

FP FLOOD PLAIN OVERLAY ZONE
(Added by Ord. 3583 (NS) adopted 9-16-70.)

Section 452.1. PURPOSE AND INTENT. The FP Flood Plain Overlay Zone (FP Zone) is designed to provide land use regulations in undeveloped areas on properties situated in the flood plain of rivers, creeks, streams, and watercourses. The purpose of this Zone is to protect the public health, safety, and welfare and reduce the financial burden on the County and its inhabitants and property owners by eliminating or reducing the need for the construction of flood control channels, dikes, dams, and other flood control improvements that would be required if scattered and unplanned development is permitted to occur. It is intended that this Zone be applied in a uniform manner to those properties within the County of San Diego not planned for urban development which in the opinion of the Board of Supervisors, after considering any available reports of the U. S. Army Corps of Engineers, State, and County officials and departments, are subject to inundation under 100-year frequency flood conditions. It is intended that this Zone will be an overlay zone and that it will be overlying and supplemental to the basic underlying land use zone or zones.

It is intended that the FP Zone will be removed from any property that is no longer subject to inundation as a result of the construction of flood control structures or facilities in accordance with Section 452.2 of this ordinance.

(Amended by Ord. 3846 (NS) adopted 2-23-72.)

Section 452.2. LAND USES.

(a) In an FP Zone the following uses are permitted:

1. Any use permitted in the underlying zone or zones subject to the same conditions and restrictions applicable to such underlying zone or zones.

2. Any irrigation structure.

3. The following uses, provided a special use permit is issued in accordance with the provisions of this ordinance:

    a. Any use permitted in an A-4 Zone subject to the same conditions and restrictions applicable to such zone.

    b. Any use listed in Section 480 or 481 of this ordinance, irrespective of whether such use is excluded from the underlying zone or zones by said sections, provided the Planning Commission or, in the event of an appeal, the Board of Supervisors determines such use is consistent with the purposes of the FP Zone.

(b) All uses permitted in the FP Zone shall be subject to the following conditions:

1. No building or structure shall be placed, erected, constructed, altered, or enlarged within the FP Zone except in accordance with all of the provisions of the San Diego County Code including but not limited to the provisions of the Building Code (Chapter 1 of Title 5 of the San Diego County Code) applicable to areas subject to inundation and Division 8 of Title 8 of the San Diego County Code applicable to drainage and watercourses.

2. No drainage or flood control structure or facility shall be placed, erected, constructed, reconstructed, altered, or enlarged within a floodway provided, however, that the existing flood control structures or facilities may be repaired and maintained; and provided further that the following facilities may be placed, erected, constructed, reconstructed, altered, or enlarged in a floodway if such facility would not unduly accelerate or increase the flow of water so as to create a condition which would be detrimental to the health or safety of persons or property:

    a. Grass-lined or similarly vegetated flood control channels either of excavated or diked section, or levees, including groins of a temporary nature to protect the same.

    b. Dams and reservoirs designed primarily for water conservation, recreation, or debris control.

    c. Erosion control works, such as, but not limited to: retards, groins, jetties, vegetated, stone, rock, or sacked concrete revetment, rock and wire mattress, pipe and wire fence, precast cribbing, drop structures, check dams, grade stabilizers and rock sills, and removal of debris from watercourses.

    d. Ground water replenishment works, such as, but not limited to: diversion dams, percolation beds, spreading grounds, and injection wells.

    e. Any similar drainage or flood control structure or facility which the County Flood Control Engineer determines would not unduly accelerate or increase the flow of water so as to create a condition which would be detrimental to the health or safety of persons or property.

3. No building designed or used for human habitation or as a place of work or by the public shall be constructed, erected, placed, or maintained in a floodway; provided, however, this restriction shall not preclude the Director of Building Inspection from authorizing the construction, erection or placement and maintenance of a temporary building within the floodway during the period from the beginning of May to the end of October.

4. No building or structure may be placed, erected, constructed, or maintained in a floodway unless the County Flood Control Engineer determines such building or structure will not adversely affect or unduly hinder, restrict, or alter the water-carrying capacity of the floodway; provided, however, this restriction shall not preclude the Director of Building Inspection from authorizing the construction, erection or placement and maintenance of a temporary building or structure within the floodway during the period from the beginning of May to the end of October.

5. No materials, vehicles, or equipment shall be stored within the floodway and outside of a building except those materials that will not create a hazard to the health or safety of persons or property in the event the storage area is inundated.

(Amended by Ord. 3846 (NS) adopted 2-23-72.)

ARTICLE XXVII-D
(Amended by Ord. 3846 (NS) adopted 2-23-72.)

FC FLOOD CHANNEL OVERLAY ZONE
(Added by Ord. 3583 (NS) adopted 9-16-70.)

Section 453.1 PURPOSE AND INTENT. The FC Flood Channel Overlay Zone (FC Zone) is designed to provide land use regulations in those areas of the flood plains of rivers, creeks, streams, and watercourses in which flood control structures and facilities are planned to be installed. The purpose of this Zone is to protect the public health, safety, and welfare by restricting the construction of buildings and structures within such Zone until such time as adequate flood protection or control works of facilities are constructed to protect persons and property. It is intended that this Zone be applied in a uniform manner to those properties within the County of San Diego, which in the opinion of the Board of Supervisors, after considering any available reports of the U. S. Army Corps of Engineers, State, and County officials and departments, are subject to inundation under 100-year frequency flood conditions. It is intended that this Zone shall be applied only to watercourses, or portions thereof, for which the Board of Supervisors has, by resolution adopted after a public hearing, approved a plan for channelizing the watercourse or portion thereof by the construction of a flood control structure or facility. It is intended that this Zone will be an overlay zone and that it will be overlying and supplemental to the basic underlying land use zone or zones. It is intended that the FC Zone will be removed from any property that is no longer subject to inundation as a result of the construction of flood control structures or facilities in accordance with the approved plan.

(Amended by Ord. 3846 (NS) adopted 2-23-72.)

Section 453.2. LAND USES.

(a) In an FC Zone the following uses are permitted:

1. Any use permitted in the underlying zone or zones subject to the same conditions and restrictions applicable to such underlying zone or zones.

2. Flood control structures and facilities.

3. The following uses provided a special use permit is issued in accordance with the provisions of this ordinance:

   a. Any use permitted in an A-1 Zone subject to the same conditions and restrictions applicable to such zone.

   b. Any use listed in Section 480 or 481 of this ordinance, irrespective of whether such use is excluded from the underlying zone or zones by said sections, provided the Planning Commission or in the event of an appeal the Board of Supervisors determines such use is consistent with the purposes of the FC Zone.

(b) All uses permitted in the FC Zone shall be subject to the following conditions:

1. No building or structure shall be placed, erected, or constructed within the FC Zone except in accordance with all of the provisions of the San Diego County Code including but not limited to the provisions of the Building Code (Chapter 1 of Title 5 of the San Diego County Code) applicable to areas subject to inundation and Division 8 of Title 8 of the San Diego County code applicable to drainage and watercourses.

2. No building designed or used for human habitation or as a place of work or by the public shall be constructed, erected, placed, or maintained in a floodway; provided, however, this restriction shall not preclude the Director of Building Inspection from authorizing the construction, erection, or placement and maintenance of a temporary building within the floodway during the period from the beginning of May to the end of October.

3. No building or structure shall be placed, erected, constructed, or maintained in a floodway unless the County Flood Control Engineer determines such building or structure will not adversely affect or unduly hinder, restrict, or alter the water-carrying capacity of the floodway; provided, however, this restriction shall not preclude the Director of Building Inspection from authorizing the construction, erection, or placement and maintenance of a temporary building within the floodway during the period from the beginning of May to the end of October.

4. No materials, vehicles, or equipment shall be stored within the floodway and outside of a building except those materials that will not create a hazard to the health or safety of persons or property in the event the storage area is inundated.

(Amended by Ord. 3846 (NS) adopted 2-23-72.)

Appendix B

COST ESTIMATES

This appendix contains an estimate of the construction, operation and maintenance, and right of way costs for concrete-lined channels, earth channels, and grass-lined channels for different reaches of the Upper San Diego River and San Vicente Creek.

No alternative structural measures were studied for reaches 1, 9, and 12 and only the concrete-lined channel was studied for reaches 3 and 11. Flood Control Channels are not justified in these reaches because the floodplains are narrow compared to the width required for channel construction and there is very little present or potential development to be protected. For reach 3, only the concrete-lined channel was studied. Earth and grass-lined channels were not studied in reach 3 as this reach consists of an 18-hole golf course, and the right of way required for an earth or grass-lined channel would require the purchase of the golf course which makes construction of these channels infeasible.

Unit Prices

Unit prices were based on material equipment and labor costs as of July 1974.

Right of Way Costs

Costs of right of way were estimated from assessor's data. Market value of land and improvement is four times the assessed value. To bring the market value to 1974 levels, the 1971 market values were increased by 25 percent. Acquisition costs were assumed to be 10 percent of the market value.

Description	Unit	Unit Price	Upper San Diego River Reach 2 Quantity	Reach 2 Cost	Reach 3 Quantity	Reach 3 Cost	Reach 4 Quantity	Reach 4 Cost
CONCRETE LINED CHANNEL								
Construction Cost								
Excavation	C.yd	$ .81	49,000	39,700	79,000	64,000	275,000	$222,800
Compacted Fill	C.yd.	.38	145,000	55,100	68,000	25,800	234,000	88,900
Concrete lining	C.yd.	40.00	20,400	816,000	41,000	1,640,000	45,200	1,808,000
Cement	Bbl.	7.00	25,500	178,500	51,250	358,800	56,500	395,500
Steel reinforcement	Lb.	.16	1,377,000	220,300	2,767,500	442,800	3,051,000	488,200
Drop Structure	L.S.							
Subtotal				1,309,600		2,531,400		3,003,400
Contingencies				131,000		253,100		300,300
Engineering				131,000		253,100		300,300
Construction Supervision				196,400		379,700		450,500
Total for Construction				1,768,000		3,417,300		4,054,500
Relocation								
Utilities				6,000				15,000
Roads and bridges				80,000				
Rights-of-way	Acres	Varies	26	57,000	48	106,000	59	130,000
Total Capital Cost				1,911,000		3,523,300		4,199,500
Interest during construction				47,800		88,100		105,000
Total Project Cost				1,958,800		3,611,400		4,304,500
EARTH CHANNEL								
Construction Cost								
Excavation	C.yd.	$ .81	161,500	$130,800			568,500	$460,500
Compacted Fill	C.yd.	.38	169,000	64,200			493,300	187,500
Riprap	C.yd.	9.70	26,100	253,200	SEE		60,000	582,000
Filter	C.yd.	4.90	8,700	42,600			20,000	98,000
Drop structure	L.S.				NOTES			175,000
Subtotal				490,800				1,503,000
Contingencies				49,100				150,300
Engineering				49,100				150,300
Construction Supervision				73,600				225,500
Total for Construction				662,600				2,029,100
Relocation								
Utilities				10,000				24,000
Roads and bridges				25,000				
Rights-of-way	Acres	Varies	40	88,000			89	196,000
Total Capital Cost				785,600				2,249,100
Interest during construction				19,600				56,200
Total Project Costs				805,200				2,305,300
GRASS-LINED CHANNEL								
Construction Cost								
Excavation	C.yd.	.87	208,000	$181,000			472,000	$ 410,600
Compacted Fill	C.yd.	.41	120,800	49,500			470,400	192,900
Grass Lining	Acre	5700	51	290,700	SEE		118	672,600
Drop structure	L.S.							200,000
Subtotal				521,200	NOTES			1,476,100
Contingencies				52,100				147,600
Engineering				52,100				147,600
Construction Supervision				78,200				221,400
Total for Construction				703,600				1,992,700
Relocations								
Utilities				12,000				34,000
Roads and bridges				30,000				
Rights-of-way	Acres	Varies	51	112,000			121	266,000
Total Capital Cost				857,600				2,292,700
Interest during construction				21,400				57,300
Total Project Costs				879,000				2,350,000

Notes: Reaches 1, 9 and 12 were not studied because of the very narrow floodplains in these reaches.
In Reach 3, presence of an 18-hole golf course makes the construction of an earth or grass-lined channel infeasible.

Upper San Diego River								*San Vicente Creek*			
Reach 5		*Reach 6*		*Reach 7*		*Reach 8*		*Reach 10*		*Reach 11*	
Quantity	*Cost*	*Quantity*	*Cost*	*Quantity*	*Cost*	*Quantity*	*Cost*	*Quantity*	*Cost*	*Quantity*	*Cost*
225,800	$182,900	207,000	$167,700	(.45)		878,000	$711,200	106,600	$86,300	15,700	$12,700
175,400	66,700	277,000	105,300	523,800	$235,700	86,000	32,700	110,000	41,800	16,300	6,200
28,800	1,152,000	38,500	1,540,000	8,200	328,000	93,800	3,752,200	38,000	1,540,000	4,700	188,000
36,000	252,000	48,100	336,700	10,250	71,800	117,250	820,800	48,100	336,700	5,900	41,300
1,942,000	310,700	2,598,800	415,800	553,500	88,600	6,331,500	1,013,000	2,595,000	415,200	319,000	51,000
					200,000						
	1,964,300		2,565,500		924,100		6,329,900		2,420,000		299,200
	196,400		256,600		92,400		634,000		242,000		29,900
	196,400		256,600		92,400		634,000		242,000		29,900
	294,600		384,800		138,600		954,000		363,000		44,900
	2,651,700		3,463,500		1,247,500		8,551,900		3,267,000		403,900
	6,000		11,000		11,000		27,000		20,000		10,000
	90,000		90,000				450,000		110,000		60,000
38	125,000	50	358,000	10	23,000	134	134,000	72	477,800	11	37,000
	2,872,700		3,922,500		1,281,500		9,162,900		3,874,800		510,900
	71,800		98,100		32,000		229,800		96,900		13,000
	2,944,500		4,020,600		1,313,500		9,392,700		3,971,700		523,900
358,000	$290,000	504,000	$408,200	(.45)		1,692,300	$1,370,800	381,200	308,800		
293,000	111,300	437,000	166,100	593,600	267,100	338,300	128,600	219,200	83,300		SEE
39,700	385,100	46,000	446,200	9,500	92,200	122,600	1,189,200	59,400	576,200		
13,200	64,700	15,300	75,000	3,200	15,000	40,900	200,400	19,800	97,000		
	250,000		250,000		200,000						NOTES
	1,101,100		1,345,500		574,300		2,889,000		1,065,300		
	110,100		134,600		57,500		288,900		106,500		
	110,100		134,600		57,500		288,900		106,500		
	165,200		201,800		86,300		433,400		159,800		
	1,486,500		1,816,500		775,600		3,900,200		1,438,100		
	10,000		18,000		18,000		43,000		35,000		
	25,000		25,000				100,000		35,000		
58	191,000	92	629,000	18	42,000	207	205,000	98	666,000		
	1,712,500		2,488,500		835,600		4,248,200		2,174,100		
	42,800		62,200		20,900		106,200		54,400		
	1,755,300		2,550,700		856,500		4,354,400		2,228,500		
372,000	$323,600	756,000	$657,700	(0.45)		1,885,000	$1,640,000	416,000	361,900		
398,200	163,300	486,500	199,500	754,700	339,600	226,900	93,000	104,400	42,800		
75	427,500	120	684,000	25	142,500	333	1,898,100	154	877,800		SEE
	250,000		250,000		200,000						
	1,164,400		1,791,200		682,100		3,631,100		1,282,500		NOTES
	116,400		179,100		68,200		363,100		128,300		
	116,400		179,100		68,200		363,100		128,300		
	174,700		268,700		102,300		544,700		192,400		
	1,571,900		2,418,100		920,800		4,902,000		1,731,500		
	14,000		25,000		25,000		60,000		40,000		
	30,000		30,000				120,000		45,000		
75	248,000	125	858,000	25	58,000	333	330,000	154	1,057,000		
	1,863,900		3,331,100		1,003,800		5,412,000		2,873,500		
	46,600		83,300		25,100		135,300		71,800		
	1,910,500		3,414,400		1,028,900		5,547,300		2,945,300		

Reach 11 was not studied for earth or grass-lined channel because of the relatively narrow floodplain.